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Monterey, California

THESIS

A MULTI-COMMODITY NETWORK DESIGN FOR THE DEFENSE LOGISTICS AGENCY

by

Robert D. Holmes Jr.

June 1994

Thesis Advisor: Robert F. Dell

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The Defense Logistics Agency (DLA) currently operates 28 depots in the United States from which it supplies over 45,000 customers with over 3 million products procured from over 10,000 suppliers. DLA plans to reduce its infrastructure and proposes to analyze its distribution system using the Strategic Analysis of Integrated Logistics Systems (SAILS) model - a mixed integer linear programming model widely used by a number of civilian organizations to make facility location decisions. The size of DLA's distribution system precludes directly evaluating all possible depot, product, and customer combinations. This thesis derives a 29 product, 113 customer aggregation scheme which facilitates SAILS execution and appears to adequately model DLA. Extensive comparisons between this aggregation scheme and others (44-, 49-, and 67-product; and 199- and 113-customer aggregations) at 100, 90, 80, 50, and 30 percent of derived depot throughput capacity show solutions to different aggregations result in virtually identical closure recommendations and total annual cost. This thesis shows how DLA can save over 300 million dollars annually through depot closure and reorganization.

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A Multi-Commodity Network Design for the Defense Logistics Agency

by

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The Defense Logistics Agency (DLA) currently operates 28 depots in the United States from which it supplies over 45,000 customers with over three million products procured from over 10,000 suppliers. DLA plans to reduce its infrastructure and proposes to analyze its distribution system using the Strategic Analysis of Integrated Logistics Systems (SAILS) model - a mixed integer linear programming model widely used by civilian organizations to make facility location and logistics network design decisions. The size of DLA's distribution system precludes directly evaluating all possible depot, product, and customer combinations. This thesis derives a 29 product, 113 customer aggregation scheme which facilitates SAILS execution and appears to adequately capture sufficient detail to accurately model DLA. Extensive comparisons between this aggregation scheme and others (44, 49, and 67 product; and 199 and 113 customer aggregations) at 100, 90, 80, 50, and 30 percent of derived depot throughput capacity show solutions to different aggregations result in virtually identical closure recommendations and total annual costs. This thesis shows how DLA can save over 300 million dollars annually through depot closure and reorganization.

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EXECUTIVE SUMMARY

This thesis shows how the Defense Logistic Agency (DLA) can save over 300 million dollars annually through depot closure and reorganization. This conclusion follows extensive analysis of DLA's distribution network using the Strategic Analysis of Integrated Logistics Systems (SAILS) model - a mixed integer linear programming model widely used by civilian organizations to make facility location and logistics network design decisions. This thesis derives a 29-product, 113-customer aggregation scheme which facilitates SAILS execution and appears to adequately capture sufficient detail to accurately model DLA. Extensive comparisons between this aggregation scheme and others (44-, 49-, and 67-product; and 199- and 113-customer aggregations) at 100, 90, 80, 50, and 30 percent of derived depot throughput capacity show solutions to different aggregations result in virtually identical closure recommendations and total annual cost.

The Defense Logistics Agency (DLA) currently operates 28 depots in the United States from which it supplies over 45,000 customers with over three million products procured from over 10,000 suppliers. DLA must reduce operating costs to accommodate declining Defense budgets. Consequently, a number of facilities has been slated for closure or realignment under the Defense Base Realignment and Closure (BRAC) Commission's 1991 and 1993 recommendations. DLA will plan further closures for 1995 using the Strategic Analysis of Integrated Logistics Systems (SAILS) model. The size of DLA's distribution system precludes directly evaluating all possible depot, product, and customer combinations. Without aggregation, data input and output would be overwhelming even if sufficient computer memory, computational ability, and storage exist to solve the resulting SAILS' mixed integer linear program.

Even with aggregation, modeling of DLA's extensive distribution system requires enormous amounts of data. This thesis uses the following information supplied by DLA: the 1992 Material Release Order files containing over 17 million material shipment transactions totaling over 1 billion pounds from which demand and customer information is obtained, depot fixed and variable costs, and depot throughput capacity information. Because of difficulty obtaining and manipulating the required files, this thesis does not directly model subsistence material which accounts for approximately 25 percent of total demand weight. Instead, it uses a conservative estimate of the depot throughput capacity. From all data, a 29-product, 113-customer aggregation scheme is developed and extensively tested on a 586 66 MHz personal computer with 261 megabytes of extended memory.

Solutions produced using the various aggregation schemes indicate that significant annual savings of over 300 million dollars can be realized from depot closures and reorganization. Recommended closures decrease fixed and variable costs by approximately 349 million dollars while increasing transportation costs by 13.5 million dollars.

I. INTRODUCTION

The Defense Logistics Agency (DLA) must reduce it operating costs to accommodate declining Defense budgets. Consequently, a number of facilities has been slated for closure or realignment under the Defense Base Realignment and Closure (BRAC) Commission's 1991 (BRAC Commission [1991]) and 1993 (BRAC Commission [1993]) recommendations. DLA will plan further closures for 1995 using the Strategic Analysis of Integrated Logistics Systems (SAILS) model (INSIGHT Inc. [1993]). SAILS is a computer program widely used by civilian companies to make plant location, warehouse location, and inventory positioning decisions (Appendix A contains the underlying mixed integer linear program at the heart of SAILS). The size of the DLA's distribution system precludes directly evaluating all possible depot, product, and customer combinations. Without aggregation, data input and output would be overwhelming even if sufficient computer memory, computational ability, and storage exist to solve the resulting SAILS' mixed integer linear program. This thesis defines aggregation schemes for DLA products, customers, and suppliers for use in SAILS.

A. DEFENSE LOGISTICS AGENCY

DLA's primary mission is timely provisioning of consumable material to Department of Defense activities during either peacetime or wartime. DLA's problem is how to maintain the current level of customer service while closing existing facilities and reducing operating costs. House [1978] succinctly states DLA's dilemma:

> The importance of the facility location problem is due primarily to the fact that distribution centers represent significant cost centers in the distribution channel... distribution depots represent points where customer service is provided through the maintenance of inventories. In many situations, it can be shown that as more facilities are sited there is a proportional increase in the amount of customer service provided...[House 1978 p. 1]

The DLA distribution system is primarily a two-echelon system where materials flow in large shipments from suppliers to depots and from these depots in smaller order quantities to the ultimate consumers. A small amount of material flows directly from vendor to customer but suppliers do not necessarily remain constant over time, and therefore this thesis models DLA's distribution system as a pure two-echelon system with no direct vendor to customer flows.

DLA manages a diverse mix of material including subsistence items, aircraft repair parts, clothing, paper products, fuel, medicines, and construction material (DLA, [1992]). To operate the distribution system, DLA has:

- six inventory control points responsible for inventory management of over three million line items.

- 28 distribution depots located throughout the United States responsible for the receipt, storage, and distribution of this material [DLA, 1992].

DLA has recently assumed greater responsibilities as the Department of Defense (DOD) attempts to reduce operating costs by consolidating operations. As the result of Defense Management Review Decisions (DMRD) issued by the Secretary of Defense [1989], the following actions have increased DLA's responsibilities:

- Consumable items previously managed by the individual services have been transferred to DLA; this action has the potential to increase the range of materials managed by 981,000 line items (DMRD 926 [1989]).
- Distribution depots previously operated by the individual services have been transferred to DLA which increased DLA's total number of depots to thirty two (DMRD 902 [1989]).

B. OBJECTIVE OF CURRENT RESEARCH

This study develops aggregation schemes for DLA products, customers, and suppliers which allow DLA's distribution system to be modeled within SAILS and allows SAILS' underlying mathematical model to be solved in a reasonable time without significant loss of fidelity. To evaluate the validity of the aggregation techniques, several commodity and customer aggregation schemes are formulated. Comparisons are made between the solutions generated from the different techniques highlighting significant variation. The base year for purposes of this study is fiscal year 1992. Historical files for fiscal year 1992 show that DLA:

- procured material from over 10,000 suppliers;
- processed and shipped over fifteen million requisitions with a total weight of over one billion pounds; and
- served over 45,000 customers including all military services and other government activities.

C. THESIS OUTLINE

Chapter II discusses the 1978 Department of Defense Material Distribution System (DODMDS) study and related literature. Chapter III discusses the aggregation schemes developed. Chapter IV provides computational experience. Chapter V presents conclusions and recommendations. Appendix A contains the underlying mathematical model used by SAILS. Appendix B provides a listing of the material groupings managed by DLA. Appendix C presents a statistical summary of the material transaction file supplied by DLA for this study. Appendix D details the four different commodity aggregation schemes. Appendix E describes the customer aggregation schemes.

II RELATED STUDIES

The DLA distribution system was examined in 1978 by the Department of Defense Material Distribution System (DODMDS) study, a joint service effort commissioned after the Vietnam War to reduce DOD operating costs. The purpose of this study was to examine the existing distribution system and recommend improvements which would support individual Service operational requirements in an effective and efficient manner. This chapter reviews this study and studies accomplished on civilian distribution networks which are useful as a foundation for developing aggregation schemes.

A. DEPARTMENT OF DEFENSE MATERIAL DISTRIBUTION SYSTEM (DODMDS) STUDY

The DODMDS study, undertaken in April 1975, examined the distribution systems operated by the Army, Air Force, Navy, Marines, and DLA within the fifty United States. This study examined the entire DOD distribution network which included maintenance depots as well as storage facilities. All material managed by these services and required within the United States and overseas was included with the exception of the following products: bulk petroleum, perishable subsistence; ammunition; chemical, biological, and radiological items; industrial plant equipment; and some major end items (*i.e.*, ships, aircraft, and strategic missiles) (DODMDS [1978] Vol I p. 9). Because of the inclusion of repairable components and the need for this type of material to be returned to maintenance facilities for repair, the material return network was examined as well. Released in 1978, the study provided an optimal distribution network for DOD, but these results were never implemented.

The DODMDS study group acknowledged a problem which is inherent in any examination of a system this extensive where data aggregation is required:

> Large scale studies have frequently been criticized for aggregating a problem out of existence and unwittingly biasing the results through the aggregation process. (DODMDS [1978] Vol I p. 27)

DLA agreed with this criticism. In their opinion, data aggregation significantly reduces the variability associated with individual items and demand locations (DLA [1978]). The major assumption underlying the DODMDS study is demand stability and this situation is not always the case with DLA's demand patterns. Hobbs and Lanagan [1992] find that demand stability for DLA requirements is an erroneous assumption. According to their study, demand variability exists on three levels:

- Examining total demand across all commodities and over a 10 year period, annual demand experiences a 33 percent decrease from a peak year to the minimum period;

- Within two commodities examined individually (Electronics and General), annual demand decreases approximately 25 and 30 percent respectively over a seven year period;

- Using two different populations of items and the six original DLA depots (Mechanicsburg, Richmond, Memphis, Columbus, Ogden, and Tracy), Hobbs and Lanagan examine the workload variability for these depots over a two year period. For population A (103,000 items), these depots experience shifts in the number of transactions from an increase of 10 percent to a decrease of 3 percent and decreases in shipment quantities from 12 percent to 20 percent. For population B (219,000 items), the number of transactions vary from an increase of 9 percent to a decrease of 7 percent and the quantities shipped vary from a plus of 2 percent to a minus 23 percent;

- Using the same two population groups (population A, 103,000 items and population B, 219,000 items) and 11 customer groupings, Hobbs and Lanagan examine the variability of demand within customer clusters over a two year period. For population A, the number of transactions processed vary from a plus 8 percent to a minus 6 percent and the actual quantities shipped varies from a minus 3 percent to a minus 29 percent. For population B, the number of transactions vary between a plus 4 percent to a minus 16 percent while the actual quantities shipped varies from a minus 3 percent to a minus 26 percent.

These results show that customer demand may not be stable between periods for a geographic location but offer no predictive estimates of future demand patterns. Experience with SAILS in the private sector (Karrenbauer [1994]) has shown that demand variability with commercial organizations far exceeds that reported by Hobbs and Lanagan [1992] and that DLA's distribution network can be meaningfully accommodated by SAILS. SAILS develops a optimal strategic distribution network (*i.e.,* determines optimal depot locations for the network operating over a long time-frame) as opposed to a tactical or operational plan designed to make daily decisions.

This study, like the DODMDS study, bases its analysis and conclusions on one year's historic data.

The aggregation techniques utilized in the DODMDS study are used as a template for the schemes of this current study. Specific similarities and differences between the aggregations of the DODMDS study and the ones presented in this thesis are addressed in follow on chapters.

B. OTHER STUDIES

In recent years substantial research has been accomplished discussing location analysis for plants, distribution facilities, retail activities, and service centers (House [1978]; Geoffrion [1976]; Geoffrion and Graves [1974]; Ghosh and Mclafferty [1987]; Khumawala and Whybark [1971]; Klincewicz [1985]; Neebe and Khumawala [1981]; Cooper [1967]; Geoffrion and Powers [1993]). According to Geoffrion and Powers [1993 p. 2], these studies have resolved the following basic distribution network planning questions:

- How many distribution centers should there be and where should they be located?
- What size should each distribution center be and what products should it carry?
- What distribution center (plant) should service each customer?
- Should all stocking points carry all products or specialize by product line?
- How should each plant's output be allocated among distribution plants/customers?

- What should the annual transportation flows be? Should pool points be used, and if so where should they be?
- For a given level of customer service, what is the cost savings for the proposed system?

On the other hand, there has been limited research conducted on the aggregation techniques necessary to facilitate data input into these models and the results these schemes have on final solutions. As House and Jamie [1981] state:

> Research conducted in the past several years has focused almost exclusively on techniques employed in planning... very little research appears to have been conducted in determining the sensitivity of planning results to the methods employed in aggregating data.(House and Jamie [1981])

Recent improvements in computers and the location models allow inputs to be much more voluminous and detailed than previously, but data aggregation is still necessary. Bender acknowledges the importance of aggregating data correctly:

> The most critical step in the analysis and design process is to determine the right level of data aggregation: the more aggregated the data, the greater the potential errors in analysis, but the simpler it is to analyze, and the cheaper it is to assemble. (Bender [1985] p. 157)

1. PRODUCT AGGREGATION

DLA manages over three million line items. Recognition of each of these products individually is impractical for any facility location model thus some product aggregation is required.

To aggregate products there are four factors according to Bender which must be considered:(Bender [1985] p. 157)

- Market: identify the top products which account for the bulk of material shipped; account for the different sales ratios in the various markets;
- Logistic: aggregate products with similar transportation rates, handling, and storage characteristics;
- Production: aggregate products with similar unit production costs and those produced in the same plants; and
- Organizational: aggregate products based on any unique requirements of the organization.

The aggregation studies reviewed in this thesis have not concentrated on product aggregations. These studies (House and Jamie [1981]; Ballou [1991] and [1993]) examine distribution systems comprised of a limited number of consumer oriented products or product lines where the need to aggregate has not been considered or the aggregation scheme is straightforward. With product aggregation, the variability inherent in individual products is reduced. Ballou [1991] diminishes the importance of product differences concluding that these differences did not play a major factor in demand cluster determinations:

> Different transport rates associated with different products do not significantly affect the number of clusters to be used. or the manner in which the clusters are formed... product differences and their shipment sizes can be eliminated as an important variable in the selection of demand clusters. (Ballou [1991] p. 14)

Civilian distribution systems typically manage similar products. Conversely, DLA handles a varied line of products. This study determines whether product aggregation schemes have an impact on depot location decisions.

2. GEOGRAPHIC CUSTOMER AGGREGATION

DLA has over 45,000 customers. Recognition of each of these customers individually is impractical for any facility location model thus some customer aggregation is required.

A number of approaches has been used by analysts to aggregate customers including grouping customers by: geographic proximity, type of customer, type of export, or specific customer service requirements. Georeferencing approaches typically rely on Standard Metropolitan Statistical Areas, individual states, and postal zip code sections to aggregate customers.

Ballou [1993] uses a method that is particularly suited for this study whereby the 900 three-digit zip codes are used as a starting point. The pair of zip codes closest to one another are combined to form one cluster. This process is repeated until the desired number of clusters is attained. The center of the cluster is determined and this point becomes the demand location for that grouping of customers.

Errors arise as transportation costs are calculated based on distance measurements from the service center to the midpoint of a cluster region as opposed to an actual location.

Hillsman and Rhoda [1978] state that three types of errors are created as the result of this estimation:

- Cost error: cost errors results from measuring distance to the service center from the aggregated point instead of from the actual demand points;
- Error is created when the service center is located at the aggregated point in which case the distance from service center to demand is zero. This measurement underestimates the true transportation costs as the center is actually serving dispersed demand; and
- Errors are created when distances from aggregated demand points to service center are used to assign demand to the nearest center. In this situation some demand may be assigned to the wrong center.

Hillsman and Rhoda [1978] analyze the magnitude of these types of errors for contrived demand patterns. They conclude that demand aggregation causes distance measurement errors up to 8% for their contrived demand patterns and expect higher percentages for actual systems.

Extending Hillsman and Rhoda's research, Casillas [1987] conducts a study which determined the effects certain factors have on the facility location problem. Casillas defines the following two types of errors created as the result of demand aggregation:

- Cost-estimate error: the difference between the cost to service aggregated demand from the optimal service location and the true cost of servicing the unaggregated demand from that location;
- Optimality error: the effect of misallocating demand to service centers and the resultant mislocation of these centers based on the use of aggregated rather than unaggregated demand.

varying "the level of aggregation, the location of aggregated demand points, and the number of service centers to be located," his study determines the effect these factors have on the objective function and the location of the service centers. Casillas' results show that the cost-estimate error is monotonically increasing with the number of source points and the level of aggregation. The results for the optimality error are not as conclusive in that there is no established pattern relating the optimality error with the number of source points and the level of aggregation. Casillas' conclusion is that in general customer aggregation does not have a significant effect on the location of service centers.

Current and Schilling [1987] also extend the research of Hillsman and Rhoda. They state that demand aggregation results in the loss of locational information which may result in suboptimal service center location. Their study devises a method of formulating the aggregated customer regions such that all but the third error (assigning demand to the nearest center) are eliminated. They compare their method to the traditional methods of forming clusters. Current and Schilling's study is accomplished on a distribution network consisting of 681 nodes aggregated into 30 and 70 demand units; five, seven, and nine source points; and uses four different sets of demand data. Using Casillas' definitions for optimality and cost errors, their study yields the following results:

- both optimality and costing errors increase monotonically with the number of sources; and
- both optimality and costing errors decrease as the number of demand clusters increase.

Research conducted by House and Jaimie [1981] on a distribution system consisting of seven market demand systems, eight warehouse networks, three shipment size groupings, and three consumer-oriented products reaches the following conclusions:

- as the number of markets increases, the outbound freight errors decreases;
- error in outbound transportation cost estimation can not be reasonably controlled with market systems of less than 100 aggregated customer points;
- shipment errors can be maintained within 2 - 3 percent with at least 150 markets; and
- as the number of distribution points increases relative to the number of markets transportation costing error increases.

Ballou [1991 and 1993] extends the research conducted by House and Jaimie [1981] examining the transportation costing error occurring in a distribution system. Ballou determines the effect the number of clusters, size of the clusters, and the number of source points have on the transportation costing error. Examining a distribution network consisting of source points ranging in number from 1 to 100, market clusters ranging in number from 50 to 900, and shipment sizes ranging from 500 pounds to a full truckload , Ballou [1993, p. 15] arrives at the following conclusions:

- the usual practice of using 100 to 200 clusters is not applicable to all problems;
- controlling the cluster size during cluster formation can significantly reduce transportation costing error;
- grouping customers by proximity is a reasonable way to form clusters and reduces transport costing error;
- costing error does not exceed 1.5 percent for carefully-formed clusters;
- as the number of sources increases the costing error also rises;
- costing errors are reduced with increased numbers of clusters; and
- costing errors increase as the number of facilities increases relative to the number of clusters.

Ballou [1993, p. 17] presents recommendations for total customer aggregations based on the number of source points, allowable error, and cluster size expressed as a percentage of total demand existing in the distribution network.

In summary, all literature suggests that as the number of customer groupings is reduced the area of the aggregated zone increases resulting in an increase in transportation costing errors. In the formulation of these customer groupings, these authors agree that:

- aggregation by proximity is a reasonable approach; and
- as the number of sources or depots increase relative to the number of customers, transportation costing error increases.

Ballou [1993] suggests that customer groupings in the 100 to 200 range is not applicable to all situations. For distribution networks with 25 source points (DLA's size), his study suggests that the number of customer groupings should be in the 300 to 500 range. This recommendation seems inapplicable to DLA because the top 100 three-digit zip codes account for approximately 84 percent of the material processed. The contention here is that a significant increase in transportation accuracy will not be gained through increasing the number of customer groupings much above 100. This study tests a range of customer groupings between 100 and 200.

3. SUPPLIER AGGREGATION

DLA has over 10,000 suppliers. Recognition of each of these suppliers individually is impractical for any facility location model thus some supplier aggregation is required.

Other than the procurement source aggregation scheme presented in the DODMDS study, there appears to be no other literature on supplier aggregation. The DODMDS study identifies the rationale for aggregating material sources as: "the large number and geographical dispersion of procurement sources; the dimensional limitations of the analytical models; and the need to make the data comprehensible to facilitate analysis" (DODMDS Vol III [1978] Section 4 p. 4.2). Because of the similar objectives, it seems reasonable to aggregate suppliers in the same fashion as customers, whereby a georeferencing system is used to identify major supplier zones and those remaining are aggregated with the major ones based on proximity. The specific approach used in the DODMDS study is addressed in subsequent sections.

III AGGREGATION SCHEMES

This chapter discusses aggregation schemes for DLA's products, customers, and suppliers. Similarities and differences between aggregations in this thesis and the DODMDS study are highlighted.

A. PRODUCT AGGREGATIONS

DLA manages over three million line items. Recognition of each of these products individually is impractical for any facility location model: Some product aggregation is required. The goal in this aggregation process is to develop categories which are sufficiently homogeneous for modeling purposes: Product groupings should have similar management, shipping, and handling characteristics. Because the DODMDS study is the only study of the literature reviewed which examines product aggregations, the DODMDS study provides the template for the schemes employed in this study.

Each item managed within the Federal supply system is assigned a national stock number (NSN) which uniquely identifies the item. The first four digits of the NSN is referred to as the Federal Supply Classification (FSC) and the last nine digits are the National Item Identification Number (NIIN). Figure 3.1 provides an example of the NSN for a steel wood screw. The four-digit FSC categorizes all material managed within the Federal system. The first two digits of the FSC identifies the major material groupings (in the example shown in Figure 3.1, FSC group 53 signifies that this item belongs to the Hardware and Abrasives group).

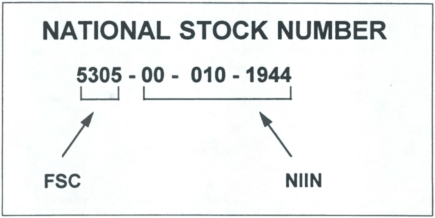

Figure 3.1: National Stock Number for a steel screw. The FSC 5305 expresses the group and class for the item: Group 53 signifies this item belongs to the Hardware and Abrasives Group and Class 05 signifies the item is a screw. The NIIN 00-010-1944 uniquely identifies this particular steel screw.

There are sixty-eight different groups managed by DLA which are listed in Appendix B. The second two digits represent the FSC class which provides a more detailed description of the type of material included in a group (Appendix B provides a detailed description of the classes available in FSC group 53 Hardware and Abrasives). The FSC forms a natural grouping mechanism since it "relates like items of supply and conversely separates unlike items of supply" (DLA H1 [1985]). Because of the large number of items and the diversity of material managed by DLA, the ease with which an aggregation scheme based on this system could be implemented, as well as the unique requirements of each service, aggregation strategies based on FSC are the most appealing approach.

The product aggregations developed are based on the Material Release Order files for fiscal year 1992 looking at the commodities listed in Table 3.1. These files are provided by the Defense Operations Research Office (DORO) and detailed material shipments for the specific commodities for the year.

Table 3.1: DLA provided the Material Release Order files for FY 1992 which lists all depot-to-customer shipments for FY 1992. All material in the Material Release Order files are labelled according to the following commodities.

Commodity	**Material Description**
C	Construction
E	Electronics
G	General
I	Industrial
M	Medical
T	Textiles

Because of difficulty obtaining and manipulating the required files, subsistence items (which accounted for 25 percent of total shipment weight in the DODMDS study) are excluded from this study. This exclusion is modeled by using a conservative estimate of capacity as discussed in the following chapter.

FSC offers an initial grouping of like items based mainly on management criteria. Shipping and handling characteristics are obtained by a statistical analysis of these groupings which shows the degree of homogeneity within FSC. The DODMDS study (DODMDS [1978] Vol III Section 4) subdivided all items within a FSC into fifteen intervals by unit weight, unit cube, and unit price. Statistical analysis of these groupings was accomplished to determine homogeneity within FSC. Four independent groups of analysts determined that like FSC's could be aggregated based on physical characteristics using the following ranking scheme:

- primary importance was placed on unit weight within FSC;
- secondary emphasis was placed on the issue weight for items within FSC; and
- the number of issues of individual items and the quantity of items issued were considered within FSC.

This aggregation process was performed iteratively where statistical analysis (calculation of mean and variance for the above characteristics) of the groupings determined whether aggregations were sufficiently homogeneous. The study derived 72-aggregate products which the DODMDS study concluded were sufficiently homogeneous for modeling purposes. These 72-aggregate products were further aggregated until 27-aggregate products resulted.

In addition to the DODMDS study, a number of other aggregation studies (See House and Jamie [1981]; Ballou [1991] and [1993]; Current and Schilling [1987]) have focused on shipment weight in transportation rate determination. As a result of conclusions derived from these studies and on DLA's evolution toward use of innovative depot-to-customer shipping modes, this thesis concentrates on weight characteristics to determine product aggregations.

A statistical analysis of the transaction files reveals the following:

- 91% of the total weight issued is composed of just 90 FSC's;
- 90% of the total issues is accounted for by just 90 FSC's; and
- 56 of the FSC's appear in both of these categories.

Because repairable components are not included, variability within FSC groupings is not as significant as that found in the DODMDS study. However, as Appendix C shows, significant variability still exists within FSC groupings. Further analysis reveals that 92% of the material shipments are less than fifty pounds. The material in the large weight categories is significantly different from the norm which helps explain the large variance found within each grouping.

The following four product aggregation schemes are developed and provided in detail in Appendix D:

- 67-aggregate products: Accomplished strictly by FSC product groupings. No distinction is made within product groupings between aviation and non-aviation related material.
- 44-aggregate products: The 67 aggregate products are further aggregated by grouping like items. A distinction is made within groupings between aviation and non-aviation related material.
- 29-aggregate products: The 44 aggregate products are further aggregated by grouping like items.
- 49-aggregate products: This approach is based on demand. Taking the top 75 FSC's by frequency of demand and total weight requisitioned, the FSC's which appear in both categories are the focus of a aggregate product and like items are grouped with these major FSC's. No distinction is made between aviation and non-aviation material within these aggregate products. Those products annotated with an asterisk in Appendix D7 represent aggregate products which are not centered around an item appearing on any of the top 75 list. Because this material is not similar to material found within any of these major groupings, separate aggregate products are created.

B. CUSTOMER AGGREGATIONS

Customer aggregation is required to model the material flows from the distribution facilities to the more than 45,000 individual DLA customers. As the DODMDS study states: "Retaining the accuracy of demand location was most significant since the structure of a distribution system (distribution center location) is heavily influenced by the geographical location of the demand and sources of supply" (DODMDS Vol III [1978] Section 2 p 2.1).

The DODMDS study (DODMDS Vol III [1978] Section 2) identifies the major installations by total demand and aggregates remaining activities with these major installations based on proximity. This process is accomplished with three-digit zip codes and the Department of Defense Automatic Address Code (DODAAC), a six-digit code which identifies individual activities. DODMDS examined the material flows from depot to customer as well as material returns from customer to depot and created 205 aggregated groupings. Where feasible, uniformed service identity was retained.

This thesis uses the three-digit zip code aggregation facilities available in SAILS to aggregate customers. Aggregation schemes are developed based on the top 259 major American cities (as identified in SAILS, see Appendix E). These cities are initially identified as the major nodes. All customers outside these zones are aggregated with these major areas based on proximity. Demand for deploying and overseas activities is assigned to the two containerization facilities: Mechanicsburg, Pennsylvania on the East coast and Tracy, California on the West coast. Of the top 250 DLA customers (as identified by three-digit zip code and total weight received), 149 have three-digit zip codes corresponding directly to the three-digit zip codes of the 259 major American cities. Attempts to use this 259-customer model in SAILS have been unsuccessful: The model dimensions are too large to permit timely solutions. Using the transaction information from the 259-customer model, two customer aggregation schemes of 199 and 113 customers are developed.

Those cities which had less than 100,000 pounds (1 million pounds for the 113-customer aggregation) of shipment activity are deleted as major nodes. The total weight received by these cities amounts to 2.6 million pounds which accounts for less than one percent of total weight shipped (39 million pounds and less than 4 percent for the 113-customer aggregation). The cities included in both aggregation schemes are provided in Appendix E and a map of the cities comprising the 113-customer aggregation is provided in Figure 3.2.

An analysis of the transaction file shows that of the top 100 three-digit zip codes (according to total weight shipped), 66 three-digit zip codes directly correspond to the three-digit zip codes of the 113 major cities. These 66 three-digit zip codes account for 51 percent of total demand weight and 70 percent of the total requisitions.

C. SUPPLIER AGGREGATIONS

Supplier aggregations are accomplished to facilitate dealing with the 10,000 material sources for the DLA distribution system. For procurement source aggregation, the DODMDS study (DODMDS Vol III [1978] Section 4) examines a number of alternate strategies and selected "the 80/20 rule" (80 percent of the procurement activity represented by 20 percent of the three-digit zip codes) as the preferred strategy: The DODMDS study identified the three-digit zip codes which provide 80 percent of the weight, 80 percent of the procurement dollar value, and 80 percent of the total transactions processed. Identified as nodes, these zip codes represent fifteen percent of the total United States zip codes

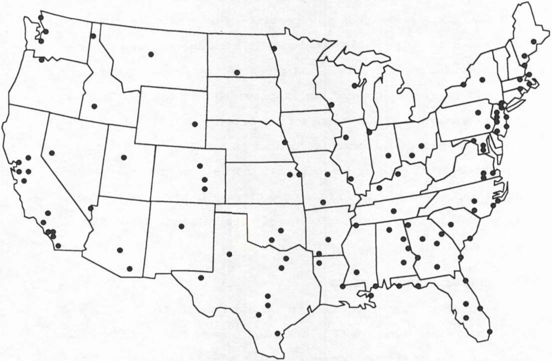

Figure 3.2: Cities comprising the 113-customer aggregation scheme. These aggregated locations are formed by taking the 259 major cities identified in SAILS and deleting those cities which account for less than 1 million pounds of demand activity (total weight received by these cities is 39 million pounds and less than four percent of total weight shipped).

and account for approximately ninety percent of the procurement activity in all three categories. The remaining sources identified by three-digit zip codes are grouped with these nodes based on proximity.

Initially this study chose to follow the same approach as the DODMDS study by identifying major supplier locations by three-digit zip codes and aggregating minor supplier zones with these primary locations. Because of difficulty with the procurement file supplied by DLA, accurate replenishment information is unavailable and therefore this study uses a supersource or single location as the sole procurement source. This location is a centralized location in Memphis, Tennessee three-digit zip code 375. The DODMDS study uses a supersource concept where the transportation rate from depot to customer is calculated as if each customer receives the aggregate product from all suppliers at the percentage of the total each supplier provides systemwide. This thesis calculates the transportation rates by aggregate product from the centralized location to each depot (*i.e.*, assuming all suppliers are located at the supersource).

D. Transportation Mode Aggregations

The DOD transportation system moves material via the shipment modes identified in Table 3.2. This study acknowledges a requisition priority by retaining the mode structure. To facilitate data input into the SAILS model, the modes which experience limited use are aggregated with the

Table 3.2: This table provides the shipment modes, frequency, and percentage of total shipments for the DLA material shipments for FY 1992 as specified in the Material Release Order files. Obtained from DLA, these files provide all depot-to-customer material shipments for FY 1992.

Description	Mode	Frequency	% of Total
Motor,truckload	A	1992099	0.1262
Motor, less truckload	B	3568067	0.2261
Van	C	5	0.0000
Driveaway	D	75	0.0000
Busline	E	1	0.0000
Military Airlift Command	F	37571	0.0024
Surface, parcel post	G	953134	0.0604
Air, parcel post	H	624534	0.0396
Govt truck	I	147486	0.0093
Small package carrier	J	1741819	0.1104
Rail, carload	K	2877	0.0002
Rail, less carload	L	168	0.0000
Freight forwarder	M	7	0.0000
LOGAIR	N	17168	0.0011
Organic Military Air	O	594	0.0000
Bill of Lading	P	2452	0.0002
Air freight/express	Q	301755	0.0191
Expedited air freight	R	311	0.0000
Scheduled truck	S	96961	0.0061
Air freight forwarder	T	98742	0.0063
QUICKTRANS	U	11299	0.0007
SEAVAN	V	152730	0.0097
Water,river, lake	W	10	0.0000
Bearer walk-thru	X	5469	0.0003
Intra-theater air lift	Y	7549	0.0005
Military Sealift Command	Z	631	0.0000
Govt watercraft	2	80	0.0000
Roll on\ Roll off	3	120	0.0000
Armed Forces Courier	4	142	0.0000
United Parcel Service	5	5017392	0.3179
Military Ordinary Mail	6	1128	0.0001
Express Mail	7	29481	0.0019
Pipeline	8	56	0.0000
Local Delivery	9	701173	0.0444
Missing/ erroneous		267551	0.0170

major modes as reflected in Table 3.3.

An analysis of the transaction files shows that 84 percent of the material is shipped using five modes of shipment.

The SAILS model has Yellow Freight and United Parcel Service rate tables available to determine transportation rates. Additionally, user-defined rates can be incorporated into the model. This rate information is used to determine an average rate per hundredweight (CWT) for each aggregate product and depot-to-customer combination.

Because rate information for the transportation modes utilized by the DOD system are not readily available, this study chose to use the UPS and Yellow Freight rates available in SAILS to estimate these averages. When the eleven aggregated modes identified in Table 3.3 are used in the SAILS model, the results produce excessive SAILS execution times. These 11 modes are therefore consolidated into six shipment categories and a shipment profile is created based on an analysis of the transaction file. Table 3.4 details the percentage of usage for each of the six modes and their categories.

Table 3.3: Aggregation of limited-use shipment modes into the 11 major mode categories for initial input into the SAILS model.

MAJOR MODE	EXPLANATION	AGGREGATED MODES	EXPLANATION
A	MOTOR, TL	C	VAN
		D	DRIVEAWAY
		P	TGBL
		V	SEAVAN
		S	SCHEDULED TRUCK SERVICE
		3	ROLL ON/ ROLL OFF
B	MOTOR, LTL	M	FREIGHT FORWARDER
K	RAIL, CARLOAD	L	RAIL, LESS THAN CARLOAD
Q	AIR FREIGHT	R	EXPEDITED AIR FREIGHT
	AIR EXPRESS	T	AIR FREIGHT FORWARDER
9	LOCAL DELIVERY	X	BEARER PICKUP
		I	GOVT TRUCK
U	QUICKTRANS	O	ORGANIC MILITARY AIR
		N	LOGAIR
G	SURFACE PARCEL POST	6	MILITARY ORDINARY MAIL
		E	BUSLINE
		J	SMALL PACKAGE CARRIER
		5	UPS
H	AIR PARCEL POST 1ST CLASS MAIL	7	EXPRESS MAIL
F	MILITARY AIRLIFT COMMAND		
Z	MILITARY SEALIFT COMMAND		
#	MISC	4	COURIER
		8	PIPELINE
		Y	INTRA THEATER AIRLIFT
		W	RIVER , LAKE
		2	GOVT WATERCRAFT
			MISSING & ERRONEOUS ENTRIES

Table 3.4: This table details the six alternate aggregated transportation modes used with model runs, the SAILS rate category used for each of these modes, and the usage percentages. This information is used by SAILS to calculate an average rate per hundredweight for each depot-to-customer link.

Mode	Rate Category	Percent
Truck Load	10000 TO 20000 lbs	32.95
Less Than Truckload	0 to 5000 lbs	42.94
Air Freight/Air Express	UPS Next Day Air	2.72
Local Delivery/Rail	400k to 999k	12.07
Surface Parcel Post	UPS Surface Parcel Post	8.38
First Class Mail MAC/QUICKTRANS	UPS Second Day Air	0.94

E. DEPOT AGGREGATIONS

This study includes the major depots examined by the DODMDS study with the addition of Naval Supply Centers in Charleston, Pensacola, and Puget Sound. In 1992, DLA used a number of secondary storage facilities which were subsequently closed. The secondary sites shown in Table 3.5 have been aggregated herein with the major depots based on proximity. With the exception of those depots identified for closure in 1993 under BRAC (Charleston, Oakland, and Pensacola) (BRAC [1993]), the major depots identified in Table 3.5 are the remaining facilities subject to the next base closure examination. Collocated depots (such as Tracy and Sharpe) are

Table 3.5: This table provides a listing of the major depots and the aggregation process this study uses to combine the secondary storage sites with the major depots. Depots that are annotated with an asterisk are slated for closure under BRAC 1993.

DEPOT CODE	MAJOR DEPOT	SEC DEPOT CODES	SECONDARY DEPOTS
AQ	SHARPE ARMY DEP LATHROP, CA 95331	B8H	SHARPE ARMY DEPOT LATHROP, CA 95331
SB	SAN JOAQUIN / TRACY , CA 95376	P23	NAS LEMOORE CA 93245
		FEZ	AFLC PACIFIC APO 96239
SM	MEMPHIS TN 38114	AD1	USA ARSENAL PINE BLUFF, ARK 71602
SA	SUSQUEHANNA MECHANICSBURG 17055	AN5 / B8N	NEW CUMBERLAND ARMY DEPOT, PA 17070
		AK5	NAH BOLLENBACH ARMY DEPOT (EUROPE)
		NFZ	NAVY PUBS & FORMS PHILA, PA 19120
		C17	ARMY MAINZ GERMANY APO 09185
		FDZ	AFLC SUPPORT EUROPE APO 09243
		NJI / NJZ	NSY PHILA, PA 19112
		NMZ	SPCC MECHANICSBURG, PA 17085
		SPT	DPSC PHILA, PA 19101
		P48	NS ROTA SP FPO 09540
SC	COLUMBUS 43215	BL6	LEXINGTON, KY 40511
		BO7	ROCK ISLAND ARSENAL, ILL 61299
		B2F	NOT FOUND
		CPH	SAVANNAH ARMY DEPOT, ILL 61074
		NGT	DPSC GREAT LAKES, ILL 60088
		P14	NAVAL AVIONICS CENTER INDIANAPOLIS, IN 46218
		P58	LOUISVILLE,KY 40214
		P64	CRANE, IN 47522
SU	DDOU OGDEN 84407		
BY	TOBYHANNA, PA 18466	BY6	TOBYHANNA ARMY DEPOT, PA 18466
		B45	SENECA ARMY DEPOT ROMULUS, NY 14541
		NHI / NHZ	NSY PORTSMOUTH, NH 03801
		NIZ	SUB BASE NEW LONDON GROTON, CT 06430
		S2L	SWIFTWATER, PA 18370
		CXL	TAUNTON, MA 02780
FP	SAN ANTONIO, TX 78421	DVQ	RANDIKOH AFB, TX 78150
		DYD	HOLLOMAN AFB, NM 88330
SR	RICHMOND, VA 23297	DWT	WASH DC 20520
		PRZ	NATC PAX RIVER, MD 20670
NO *	OAKLAND, CA 94625	DZK	TRAVIS AFB CA 94535
		PAZ	NAS ALAMEDA CA 94501
		P23	NAS LEMOORE CA 93245
		P24	NAS MOFFETT CA 94035
		P63	CONCORD, CA 94520
		S2C	BERKLEY, CA 94710
FF	MCCLELLAN AFB SACRAMENTO, CA	BS6	SACRAMENTO ARMY DEPOT CA 95813
ND	SAN DIEGO, CA 92132	PDZ	NAS NORTH ISLAND SAN DIEGO, CA 92135
		PMZ	NAS MIRAMAR CA 92145
		PSZ	PT MUGU CA 93042
		P71	SEAL BEACH, CA 90740
		Q6W	NARF SAN DIEGO, CA 92312
MB	BARSTOW CA 92311	PEZ	MCAS EL TORO SANTA ANA CA 92709
NB	JACKSONVILLE, FLA 32212	PJZ	NAS JACKSONVILLE, FL 32212
		Q16	NAS CECIL FIELD FL 32215
		XEI / XHI / XYI	MIAMI, FL 34038
NN	NORFOLK, VA 23512	PNZ	NAS NORFOLK,VA 23511
		P72	YORKTOWN, VA 23691
		Q6R	NARF NORFOLK, VA 23512
NR *	CHARLESTON, SC 29411	QHZ	CHARLESTON, SC 29408
BA	ANNISTON ARMY DEPOT AL 36201	B64	REDSTONE ARSENAL, AL 35898
MA	ALBANY, GA 31794	T1H	ALBANY, GA 31704
		U9M	ALBANY, GA 31704
NU	PUGET- BREMERTON NSY WA 98314	BU5	ARMY DEPOT HERMISTON, OR 97838
		N66	TRIDENT PROG BREMERTON, WA 98315
		N76 / N96	STRAT WPNS SILVERDALE, WA 98383
		PKZ	NAS WHIDBEY IS OAK HARBOR, WA 98277
BK	LETTERKENNY ARMY DEPOT, PA 17201		
BR	RED RIVER ARMY DEPOT TEXARKANA, TX 75507	B8R	RED RIVER ARMY DEPOT TEXARKANA, TX 75507
FG	HILL AFB, UT 84056	BP4	PUEBLO, CO 81001
		BT4	TOOLE ARMY DEPOT, UT 84074
FH	TINKER AFB OKLAHOMA CITY, OK 73145	SGM / SKR	ATCHISON, KS 66002
FL	WARNER ROBINS AFB GA 31098		
NA *	NSC PENSACOLA, FL 32508		
PT	MCS CHERRY PT, NC 28533		
SN	NEW CUMBERLAND PA 17070		
B5	ARMY DEPOT CORPUS CHRISTI, TX 78429	PCZ	ARMY DEPOT CORPUS CHRISTI, TX 78429

maintained as separate entities. Figure 3.3 provides the relative locations of the 28 major depots.

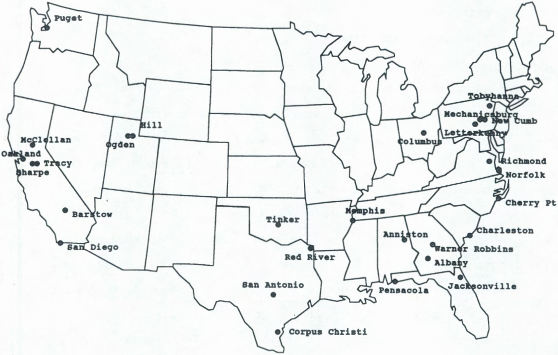

Figure 3.3: The relative location of the 28 major depots where secondary storage facilities are aggregated with the major depots based on location proximity.

IV. COMPUTATIONAL EXPERIENCE

This chapter contains detailed information on test data, scenarios tested, and solutions obtained using SAILS.

A. DATABASE

1. TRANSACTION FILE

The Material Release Order files for fiscal year 1992 are obtained from the Defense Operations Research Office (DORO) in Richmond, Virginia. Using the SAS software package (SAS Institute Inc [1990]) on an AMDAHL 5995-700A mainframe, data from the Material Release Order files are summarized and manipulated into a transaction file (which is customer demand data) in the correct format for SAILS model input. Initially, the Material Release Order file is comprised of approximately 17 million records. After extracting those requisitions created during the base year and removing erroneous records, a transaction file comprised of 15.8 million material shipments and totalling 1.032 billion pounds is created.

Due to the size of this transaction file, product aggregation is accomplished outside the SAILS model. Four separate transaction files representing each of the product aggregation schemes detailed in Chapter 3 is created for input into SAILS. These files are formatted in the outbound transaction file format (TF4)(INSIGHT Inc., SAILS Users Manual [1993]) required for input into the SAILS model as depicted in Table 4.1. To limit the size of the input file herein, shipment date information is not retained. As a result, all transactions for the period examined are assumed to be processed on julian date 92001. This process can underestimate total transportation costs as the model develops transportation rates based on the shipment profile depicted in Table 3.4.

Table 4.1: SAILS Outbound Transaction File Data Elements. Four separate transaction files representing each of the alternate product aggregation schemes is created for input into SAILS.

Data Element	DESCRIPTION
Customer Class	shipment mode information
Customer Aggregation Code	three-digit customer zip code
Stock Code	aggregate product number
Quantity	total number of transactions
Original DC code	3-character Depot Code
Julian Date	92001 (total annual demand)
Extended Weight	total weight shipped for that aggregate product, depot-to-customer link

The transaction file is sorted and summarized by aggregate product number, three-digit customer zip code, depot, and shipment mode. The total weight shipped for each aggregate product and depot-to-customer link is calculated by multiplying the total number of transactions for that link by the mean extended weight (an average calculated by multiplying requisition quantity times unit weight). File sizes for the four transaction files are provided in Table 4.2.

Table 4.2: Four different Outbound Transaction Files are generated based on the alternate product aggregation schemes employed. This table details the total number of transactions and file sizes for each of these files.

Product Aggregation Scheme	Total # of Aggregate Transactions	File Size (megabytes)
"29"	309,300	36.2
"44"	360,497	42.2
"49"	464,955	54.4
"67"	388,001	45.4

2. FACILITIES

Cost and throughput capacity information for the distribution depots identified in previous sections are developed based on information provided by DORO and DLA Headquarters. Estimates of depot fixed and variable costs are based on information provided by DORO and are listed in Table 4.3. This information represents fiscal year 1989 estimates of depot costs. Since these figures are estimates, no attempt to convert these costs to fiscal year 1992 is considered. Fixed costs are explicitly expressed and are input into the model to the nearest hundred thousand dollars. Cost information for Marine Corps facilities at Barstow, Albany, and Cherry Point are not provided. Fixed costs for these facilities are estimated at ten million dollars.

Variable costs provided by DORO are in unit cost per transaction. Because all transactions in the SAILS model are based on CWT, conversion is required. This study finds an estimated average weight per transaction and multiplies this figure by the number of transactions processed by each depot as a rough estimate of total weight processed by the depot. The variable cost per CWT is then determined by dividing the total variable cost for that depot by the total CWT processed. Both depot fixed and variable costs are provided in Table 4.3.

Depot throughput capacity is calculated based on estimates provided by DLA headquarters. These estimates are based on the number of transactions a facility could handle in a day at peak capacity. Since all model calculations are based on CWT, conversion to the amount of CWT each facility could handle is required. Additionally, these calculations need to be annualized. The conversion process is similar to the variable cost calculation where an average weight per transaction is estimated. This average is multiplied by the maximum number of transactions the facility could handle daily and a conservative estimate of the number of work days in a year (250): Only 250/365 (68 percent). The resulting throughput capacity is shown in Table 4.3. Because of the close proximity of Mechanicsburg and New Cumberland, DLA Headquarters expresses their throughput capacity as one total which this study splits in half and reports for each facility separately. This situation also exists for Sharpe and Tracy on the West coast.

Table 4.3: The depot fixed and variable costs and throughput for FY 92 used in the SAILS model.

Depot	Fixed Cost (000)	Variable Cost per CWT	Model Throughput (million pounds)
Columbus	17900	10.7775	150
Memphis	31200	11.9934	310
Mechanicsburg	24700	10.1335	510
Tracy	30200	11.9571	290
Ogden	18200	2.5868	380
Richmond	21200	10.6428	230
Letterkenny	15000	43.16498	50
New Cumberland	22700	26.8313	510
Anniston	8000	45.666	40
Sharpe	14600	39.0389	290
Tobyhanna	5400	45.0523	37
Red River	17900	36.2445	140
Corpus Christi	2400	21.7966	50
Oakland	19000	12.8446	67
San Diego	15100	9.1073	160
Puget Sound	6800	12.3212	60
Norfolk	28700	13.325	210
Charleston	8200	9.8786	170
Jacksonville	6800	9.7052	64
Pensacola	6000	9.2826	60
McClellan AFB	13000	30.3438	97
San Antonio	15200	27.1729	150
Tinker AFB	16500	21.7179	70
Hill AFB	9800	22.0196	170
Warner Robbins	13700	24.8766	140
Cherry Point	10000	10.00	40
Barstow	10000	10.00	17
Albany	10000	10.00	16

B. RUN DESCRIPTIONS

The SAILS model is run under Windows NT on a 586 66MHz personal computer with 261 megabytes of extended memory and one gigabyte of disk space. With the smaller models (less than 49 products and 113 customers), SAILS requires about 125 megabytes of extended memory to operate. The maximum level of extended memory required is 225 megabytes occurring with 199 customer aggregations.

The approach here is to systematically reduce throughput capacity across all depots to examine the effects these reductions have on total costs and the recommended depot closures. Five separate versions of the model are run for each of the aggregation schemes at full depot throughput capacity, and at 90%, 80%, 50% , and 30% of that capacity. Additionally, the throughput capacity violation penalty (available in the SAILS model) is maintained at a high level to ensure no capacity violations within a depot.

Recall that DLA subsistence items which account for approximately 25 percent of total demand weight are not directly modeled in this thesis. The subsistence demand weight is indirectly modeled by using a conservative estimate of depot throughput capacity where a 250 day work year is used instead of a 365 day work year (possible during peak periods).

Runs are accomplished under the four alternate product aggregation schemes, with 113-customer aggregations, and at the five alternate depot throughput capacity levels. To determine the effects of a different customer aggregations, additional runs are accomplished with a 199-customer aggregation, 29-aggregate products scheme and at five alternate depot throughput capacity levels.

Within SAILS, the ability exists to specify a maximum distance between depot and customer. For all runs with the exception of one test case, this distance is set at the default setting of 7500 miles - essentially unrestricted.

C. RESULTS

Table 4.4 provides the number of variables and constraints for the different models. Intuitively, it would be reasonable for the number of variables to increase as the number of aggregate products increases, but this is not always the case. Recall that the 67-aggregate product scheme is created by aggregating products by the two-digit product group. The 44- and 29-aggregate product schemes are simply further aggregations of the 67-aggregate product scheme. Table 4.4 shows that different aggregation schemes for the 44- and 29-aggregate product schemes create different depot-to-customer grouping combinations. Recall that the approach is slightly different for the 49-aggregate product scheme: Aggregate products are created around those FSC's which experience significant demand. This accounts for the higher number of variables. By expanding the number of customer aggregations, both the number of constraints and variables increases dramatically as expected.

Table 4.4: Five versions of a model depicting the DLA distribution system are created in SAILS based on different product and customer aggregation schemes. This table describes the number of constraints and variables for each of these SAILS models. By expanding the number of customer aggregations, both the number of constraints and variables increases dramatically as expected.

Aggregate Products	Customer Aggregations	Constraints	Variables
29	113	3,308	78,971
44	113	3,308	74,708
49	113	3,308	80,132
67	113	3,308	67,609
29	199	5,802	132,777

The SAILS model develops an optimal strategic distribution network (*i.e.*, determines optimal depot locations for a network operating over a long time-frame) as opposed to a tactical or operational plan. As part of this strategic modeling, SAILS sole-sources aggregate products to a specific depot. SAILS creates two reports to help show the effect of sole-sourcing. The *accounting baseline* reports the tactical statistics on actual day-to-day operations and the *model* *baseline* reports the same statistics prior to optimization where aggregate products are sole-sourced to a specific depot.

Table 4.5 summarizes *accounting baseline* (actual depot-to-customer shipments by "product bundle" - an aggregate product before sole-sourcing), *model baseline* (depot-to-customer shipments after sole-sourcing or assignment of an aggregated product group to a specific depot) and the optimal solution for the 29-aggregate products, 113-customer aggregation, full-capacity model. Comparisons between the baseline and depot capacities reveal that Albany is the only depot which exceeds calculated capacity (this deviation is only 29,000 CWT; a minimal amount in comparison to total weight shipped). Test runs show that increasing Albany's throughput capacity by this amount has no effect on solutions.

Figures 4.1 and 4.2 graphically depict depot throughput capacity, *accounting baseline*, and *model baseline* for the 29-aggregate products, 113-customer aggregation, full capacity model. Apparent in these graphs and in Table 4.5 is the fact that the depots are not operating at or even near full capacity.

Table 4.5: FY 1992 Transaction Files show by depot the accounting baseline (actual depot-to-customer weight shipped), *the model baseline* (depot-to-customer shipment weight after the aggregate product has been sole-sourced to a specific depot), and the optimal solution for the 29-aggregate product, 113-customer aggregation SAILS model.

Depots	Depot Code	Model Throughput (cwt)	Model Baseline Weight (cwt)	Accounting Baseline Weight (cwt)	Optimal Solution Weight (cwt)
Sharpe AD	AQ	2900000	45352	141866	0
San Joaq/ Tracy	SB	2900000	2334277	1877995	0
Memphis	SM	3100000	2038131	2292073	0
Mech	SA	5100000	1548063	1574424	4521065
Columbus	SC	1500000	684681	647122	0
Ogden	SU	3800000	986238	1228332	3778513
Tobyhanna	BY	370000	96	3844	0
San Antonio	FP	1500000	8775	31988	0
Richmond	SR	2300000	1637899	1311861	0
Oakland	NO	670000	312544	262013	0
McClellan AFB	FF	970000	0	5796	0
San Diego	ND	1600000	51429	64716	0
Barstow	MV	170000	11731	13104	0
Jacksonville	NB	640000	137365	115344	639065
Norfolk	NN	2100000	4294	20577	0
Charleston	NR	1700000	0	8163	0
Anniston AD	BA	400000	33	9024	0
Albany	MA	160000	220204	189139	0
Puget-Bremerton	NU	600000	52	13343	422699
Letterkenny	BK	500000	16949	21409	0
Red River	BR	1400000	55663	112362	0
Hill AFB	FG	1700000	4275	16279	562752
Tinker AFB	FH	700000	41933	35435	0
Warner Robbins AFB	FL	1400000	202	5893	0
NSC Pensacola	NA	600000	0	1691	0
MCS Cherry Pt	PT	400000	1910	2273	0
New Cumberland	SN	5100000	179007	314294	0
Corpus Christi	B5	500000	39	782	397003
Dummy Dist		0	0	0	0

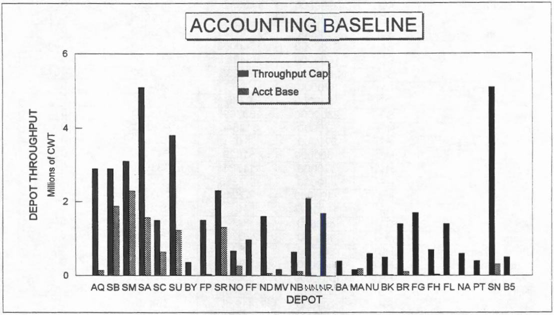

Figure 4.1: FY 92 Comparison of the depot throughput capacity to actual throughput for the 29-aggregate product, 113-customer aggregation SAILS model. For example, Mechanicsburg (depot code SA) has an estimated throughput capacity over five million CWT but has actual throughput of less than two million CWT.

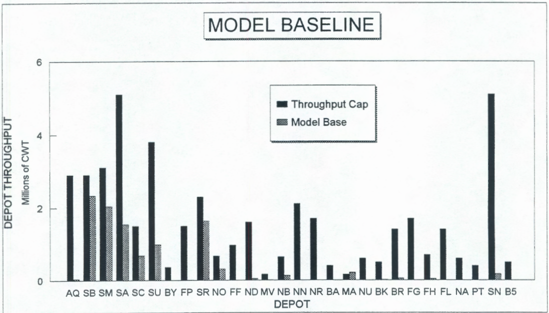

Figure 4.2: Comparison of the depot throughput capacity to baseline model throughput for the 29-aggregate product, 113-customer aggregation SAILS model. When compared to the accounting baseline this shows the minimal effect sole-sourcing aggregate products has on individual depot capacity utilization.

As depot throughput capacities are reduced, this restriction should increase total costs. Figure 4.3 shows that, as expected, throughput capacity is reduced and total operating costs increase.

Table 4.6 summarizes costs for accounting baseline, model baseline, and the optimal solution. Significant cost savings are suggested: Modeled savings total over 300 million dollars.

Figure 4.3: Depicts the total operating costs for each of the five depot throughput capacities examined for the 29-aggregate products, 113-customer aggregation SAILS model.

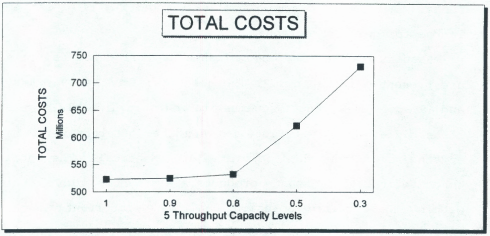

Table 4.6: Cost Summarization for the 29-aggregate products, 113-customer aggregation SAILS model.

Costs	Accounting Baseline	Model Baseline	Optimal
Fixed Costs	418,200	391,000	68,700
Variable Costs	119,550	114,777	87,990
Capacity Viol	291,385	621,511	
Replenishment	10,092	10,756	12,470
Outbound	408,202	342,182	353,999
Total (excluding penalty)	956,044	858,715	523,159

For purposes of this study, the solution gap (the difference between a bound on the best possible solutions and the best solution obtained) is three percent or less of total costs. A detailed discussion of each model run is presented in the following paragraphs.

Results of the runs accomplished at full depot capacity are presented in Table 4.7. The solutions for the 29-, 44-, and 49-aggregate product schemes are indistinguishable: Total costs differ by only $30,000 between the different versions and the recommended depot closures are identical. The total costs for the 67-aggregate products are slightly higher, but within the required solution gap. More importantly, the recommended depot openings differ by one facility. Unlike alternate solutions, this solution recommends that San Diego remain open instead of Puget. Table 4.7 shows that if the common configuration from the 29-, 44-, and 49-aggregate products model is fixed in the 67-aggregate product model, a smaller solution gap results. This shows that a number of alternate DLA depot configurations are realizable, all with comparable cost savings.

Table 4.8 presents results obtained when all depots are only allowed 90 percent of their estimated throughput capacity. As expected, total costs for the 29-aggregate product model are higher than at full capacity.

Table 4.7: Solutions to the full capacity model with 113-customer aggregation. Alternate product aggregations produce the same depot closure decisions. The solution gap represents the difference between a bound on the best possible solution and the best solution obtained.

Aggregate Products	Remarks	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Open Depots
29		59	523,159	10	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus
44		27	523,191	5.225	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus
49		35	523,161	10	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus
67		44	525,329	10	6	Mech/ Ogden/ San Diego/Jax/ Hill/ Corpus
67	Locked all depots closed except 6 open in the 29-aggregate products solution	25	523,223	7.894	6	Mech/ Ogden/ Jax/ Puget/ Hill/ Corpus

Table 4.8: Solutions to the 90 percent capacity model with 113-customer aggregation. Alternate product aggregations produce the same depots closure decisions. Solution gap represents the difference between a bound on the best possible solution and the best solution obtained.

Aggregate Products	Remarks	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Open Depots
29		57	524,982	11	5	Mech/ Ogden/ San Diego Jax/ Hill
29	Locked open depot solution from the full capacity run	31	525,985	12	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hill/ Corpus
44		35	525,051	1.256	5	Mech/ Ogden/ San Diego Jax/ Hill
49		57	526,512	2.71468	5	Mech/ Ogden/ San Diego Jax/ Hill
67		37	526,018	10	6	Mech/ Ogden/ San Diego Jax/ Puget/ Hill
67	Locked all depots closed except 5 open in the 29-aggregate product solution	28	524,884	8.886	5	Mech/ Ogden/ San Diego Jax/ Hill

A reduction in the number of open depots is apparent when comparing the full and 90 percent capacity versions: San Diego, a larger depot, replaces both Puget and Corpus Christi. Because total throughput capacity available at both Puget and Corpus Christi is less than that available at San Diego, this alternative is a viable one.

When the solution for recommended depot closures from the full capacity run is established in the 90 percent capacity version, both the recommended number of open depots and total costs increase as expected. However, both solutions are within the required solution gap reinforcing the idea that a number of alternate solutions is possible.

In the 90 percent capacity model, the recommended depot configuration for 67-aggregate product version differs from the others. In this version, Puget remains open which results in six total depots remaining open as opposed to five from the other versions. As the depot configuration from the others is established in the 67-aggregate product model, total costs and the solution gap are less than the previous version.

With 80 percent capacity, total operating costs are expected to increase. Table 4.9 shows that all versions result in these cost increases and that depot configurations are varied among the different models: 29- and 67-aggregate product versions agree with low solution gaps and the 44- and 49-aggregate product versions agree with slightly higher solution gaps. When the depot configuration from the 29-

aggregate product version is fixed in the 44- and 49-aggregate product models, solution gaps increase. Solution gaps from these subsequent runs are still within study requirements and therefore represent viable alternate solutions.

At 50 percent capacity, the restricted models become much more difficult to solve and the results vary. Solution gaps are higher than three percent of total costs and attempts to reduce them result in run times in excess of four hours. Furthermore, attempts with all models to "lock in" the 29-aggregate product solution for comparison purposes also result in long run times. The results provided in Table 4.10 reflect solutions that are within solution gaps of less than five percent.

Table 4.9: Alternate solutions to the 80 percent capacity model with 113-customer aggregation. Alternate product aggregations produce the same depot closure decisions.

Aggregate Products	Remarks	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Open Depots
29		129	532,002	2.554	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hill/ Corpus
44		82	532,495	10	5	San Joaq/ Mech/ Ogden Jax/ Corpus
44	Locked open 7 depots from the 29-aggregate products solution	49	535,251	12.756	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hill/ Corpus
49		73	535,278	10	5	San Joaq/ Mech/ Ogden Jax/ Puget
49	Locked open 7 depots from the 29-aggregate products solution	30	535,347	12.94053	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hill/ Corpus
67		80	531,874	2.48	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hill/ Corpus

Table 4.10: Solutions to 50 percent capacity model with 113-customer aggregation. Run times in excess of four hours are experienced when attempting to remain within the three percent solution gap. Although depot closure recommendations are not uniform among all models, six common depots are recommended to remain open.

Aggregate Products	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Open Depots
29	54	622,512	28	9	San Joaq/ Memphis/ Mech Columbus/ Ogden/ San Antonio Richmond/ San Diego/ Barstow
44	41	601,640	20	9	San Joaq/ Memphis/ Mech Columbus/ Ogden/ Richmond San Diego/ Jax/ Puget
49	59	611,568	25	11	San Joaq/ Memphis/ Mech Ogden/ Richmond San Diego/ Barstow/ Jax/ Puget Hill/ Cherry Pt
67	37	636,576	30	12	San Joaq/ Memphis/ Mech Columbus/ Ogden/ Richmond San Diego/ Jax/ Albany Puget/ Tinker/ Cherry Pt

Run times for the 30 percent capacity models are excessive. Results are obtained for the 44-, 49-, and 67-aggregate product models, but not within the required solution gap (three percent of total costs). As shown in Table 4.11, a successful run is attained for the 29-aggregate product version, but requires over eight hours of run time. An interesting situation occurs at the 30 percent capacity levels for all versions of the model: Hill is forced into the solution. Regardless of the throughput violation penalty setting, Hill consistently exceeds capacity by 53,000 CWT. Therefore, to achieve any results, the throughput capacity for Hill is increased by 53,000 CWT.

Table 4.11: Solutions to the 30 percent capacity model with 113-customer aggregation. Run times in excess of eight hours are experienced when attempting to remain within the three percent solution gap. All aggregations report some depot closures and four common depot closures are recommended regardless of which model is used.

Aggregate Products	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Closed Depots
29	511	730,515	10.12137	16	Tobyhanna / McClellan / Barstow Norfolk / Anniston / Albany / Letterkenny Tinker / Cherry Point
44	28	792,601	50	19	Tobyhanna / McClellan / Anniston Letterkenny / Red River / Corpus Christi
49	68	792,845	45	19	Tobyhanna / McClellan / Anniston Letterkenny / Red River / Corpus Christi
67	29	777,775	50	17	Tobyhanna / McClellan / Anniston Albany / Letterkenny / Red River / Cherry Point / Corpus Christi

A 29-aggregate product, 199-customer aggregation model has been created to determine the effect additional customer zones have on total costs. Recall that numerous studies report a decrease in transportation costing errors when the number of customers is increased. Results from this model are compared to the solutions from the 29-aggregate product, 199-customer aggregation model. At full capacity, no real difference is noted as the same six depots remain open and total costs are near equivalent. Results from the 90, 80, 50, and 30 percent depot throughput capacity models for this version differ from those of the 29-aggregate product, 113-customer aggregation version. Additional runs have been required where the solution for 29-aggregate product , 113-customer aggregation model is fixed in these subsequent models. Table 4.12 shows that these additional runs provide equivalent or lower solution gaps. Based on these results, additional customer zones would not result in increased detail or significant differences in total operating costs.

All model versions up to this point have not restricted the maximum distance between depot and customer. As this distance is limited, more depots may be required to satisfy customer demand or the solution may retain high cost and less efficient facilities just to meet this restriction. These additional facilities improve delivery times and customer service yet increase total operating costs. With recent improvements in transportation services, delivery times have been improved significantly. Therefore, the additional cost to retain depots to maintain customer service levels may not be warranted under current conditions. This study ran a model with the depot to customer distance restricted to 1000 miles for the 29-aggregate products, 113-customer aggregation, full capacity model. Table 4.13 compares the results between the restricted and unrestricted versions.

Table 4.12: Solutions for the 29-aggregate products, 199-customer aggregation model demonstrate that different customer aggregations produce essentially the same depot closure decisions.

Depot Thruput Capacity %	Remarks	Run Times (min)	Total Costs (000)	Soln Gap	Number of Open Depots	Open Depots
Full		118	523,159	10	6	Mech/ Ogden/ Jax Puget/ Hill / Corpus
90		132	524,600	11	6	Mech/ Ogden/ San Diego Jax/ Hill/ Corpus
90	Locked open the depot solution from the 29-aggregate products 90 % capacity run	63	524,893	11.294	5	Mech/ Ogden/ San Diego Jax/ Hill
80		173	533,751	10	5	San Joaq / Mech / Ogden Jax / Hill
80	Locked open the depot solution from the 29-aggregate products 80% capacity run	141	533,521	9.77	7	Mech/ Ogden/ San Diego Jax/ Puget/ Hill / Corpus
50		82	634,831	30	12	San Joaq / Memphis/ Mech Columbus / Ogden / Richmond San Diego / Barstow / Albany Jax / Hill / Cherry Point
50	Locked open the depot solution from the 29-aggregate products 50% capacity run	29	631,901	27.07	9	San Joaq / Memphis/ Mech Columbus / Ogden / San Antonio Richmond / San Diego / Barstow
30		64	792,591	40	20	all open except Tobyhanna McClellan / Anniston Letterkenny / Red River
30	Locked open the depot solution from the 29-aggregate products 30% capacity run	36	777,594	25	16	all open except Tobyhanna McClellan / Barstow / Norfolk Anniston / Albany / Letterkenny Tinker / Cherry Point

When this distance is restricted, total operating costs rise: The increase is the result of retaining higher-cost facilities sufficiently close to "reach" customers. Figure 4.4 shows that a small percentage of total demand is satisfied beyond a 1,000 mile range even when there is no range restriction: This implies that there should not be a significant change in outbound costs as range is restricted to 1,000 miles which is the case.

An additional run is made with a 300-mile limitation to determine the effects on total costs and the number of recommended depots remaining open. As expected total costs increase dramatically and the number of open depots increases to 16. In this solution, both capacity violation penalties and lost demand penalties (where it is more economical to not satisfy certain levels of customer demand) are incurred.

Table 4.13: Two models are created where the maximum distance between depot and customer is set at 7500 miles (unrestricted) and 1000 miles (restricted). This table shows that cost for the two models only varies slightly.

	Fixed Costs	Variable Costs	Replenisment Costs	Outbound Costs	Total Costs	Depots
Restricted 1000 mile limit	83200	105925	10659	354993	554777	Sharpe / Mech / Ogden Jax / Tinker / Corpus
Unrestricted 7500 mile limit	68700	87990	12470	353999	523159	Mech / Ogden / Jax Puget / Hill / Corpus

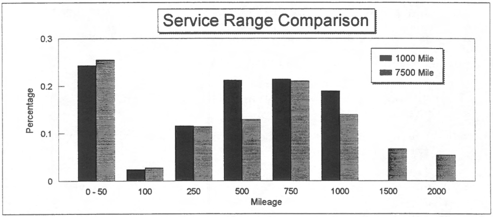

Figure 4.4: Two models are created where the maximum distance between depot and customer is either 7500 miles (unrestricted) and 1,000 miles (restricted). This histogram presents the percentage of customer demand satisfied at the various depot to customer distances. Because most demand is satisfied within the 1,000 mile range even when range is unrestricted, there is not a significant increase in total costs.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis shows how the Defense Logistics Agency (DLA) can save over 300 million dollars annually through depot closure and reorganization. This conclusion comes from extensive analysis of DLA's distribution network using the SAILS model. This thesis derives a 29-product, 113-customer aggregation scheme which renders a SAILS model of DLA that is easy to use and retains essential fidelity. Extensive comparisons between this aggregation scheme and others (44-, 49-, and 67-product; and 199- and 113-customer aggregations) at depot throughput capacities of 100, 90, 80, 50, and 30 percent of remaining capacity show that:

- DLA depots currently have excess throughput capacity available; and
- alternate solutions are possible under the current DLA distribution network.

A discussion of each of these points is presented in the following paragraphs.

DLA depots currently have excess capacity. Even when customer service range is restricted to 1,000 miles from the supplying depot, significant cost reductions in distribution network costs can be achieved without a corresponding decrease in customer service levels.

Results from the different aggregation schemes show that alternate solutions are possible at about the same cost level. As the solution from the recommended model version is fixed in those models which deviate from the 29-product, 113-customer aggregation version equivalent solutions are obtained. For this reason and the fact that the smaller version results in responsive SAILS execution, the 29-product, 113-customer aggregation model is recommended to model the DLA distribution network.

Recall that a customer service restriction where the maximum distance between depot and customer is restricted to 1000 miles led to an increase in total operating costs of over 30 million dollars. As this distance is limited, more depots may be required to satisfy customer demand or the solution may retain high cost and less efficient facilities just to meet this restriction. This study contends that with recent improvements in transportation services and delivery times no significant improvement in customer service is obtainable by ensuring depots are located "close" to or even collocated with all customers.

B. RECOMMENDATIONS

Though the personal computer version of the SAILS model used in this study accommodates a large transaction file, certain aspects of model setup should still be performed outside SAILS . Because SAILS does not possess all of the rate structures for modes used by DOD, this study recommends that transportation rates for each product aggregation, depot, and customer link be developed outside the model and provided as user-defined values. Because of the limited nature of this study and the lack of readily available data, this approach has not been feasible.

DLA depots currently have excess capacity. Depot closure and reorganization is inevitable under declining Defense budgets. This thesis has demonstrated the flexibility of the SAILS model and its usefulness as a tool to make these closure decisions. Though major concerns exist within DLA about data aggregation, this thesis has shown that data aggregation does not lead to significant modeling discrepancies within SAILS. The 29-aggregate product, 113-customer aggregation model is the means to model DLA's distribution network and SAILS is the tool to make these depot closure decisions.

APPENDIX A

The following mathematical formulation is the general form of the SAILS model:

MODEL FORMULATION

Indices

i	Products (aggregated groups of National Stock Numbers)
v	Suppliers (aggregated supplier regions)
d	Distribution depots
c	Customers (aggregated customer regions)

Data

$SUP_{i,v}$	Supplies of each product by supplier
$BUY_{i,v}$	Cost of each product by supplier
$INB_{i,v,d}$	Inbound transportation cost per product unit,by vendor/depot
$VCST_{i,d}$	Variable handling cost by product/depot
$FCST_d$	Fixed cost of operating the depot
$BRDN_{i,d}$	Burden rate per product unit by depot
$LCAP_d$ $UCAP_d$	Lower/Upper capacity of depot (in burden units)
$OUTB_{idc}$	Outbound transportation cost per product unit, by depot/customer
$OUTBD_{ivc}$	Outbound transportation cost by product from vendor to customer
$DEM_{i,c}$	Demand by product/customer

VARIABLES

$X_{i,v,d}$	Inbound flows by product from supplier to depot
$Y_{i,d,c}$	Outbound flows by product from depot to customer
Z_d	Binary variable to open/close depot
$Q_{i,d,c}$	Binary variable for sole sourcing by product/depot to customer
$P_{i,v,c}$	Plant direct shipments by product from supplier to customer

FORMULATION

MIN $\Sigma_{ivd}(BUY_{iv} + INB_{ivd} + VCST_{id})X_{ivd} + \Sigma_{idc}(OUTB_{idc}Y_{idc}) + \Sigma_d(FCST_d Z_d) + \Sigma_{ivc}(BUY_{iv} + OUTBD_{ivc})P_{ivc}$

subj to

1) $\Sigma_d X_{ivd} + \Sigma_c P_{ivc} \leq SUPPLY_{iv} \quad \forall\ i,v$

2) $\Sigma_d Y_{idc} + \Sigma_v P_{ivc} \geq DEM_{ic} \quad \forall\ i,c$

3) $\Sigma_{iv}(BRDN_{id}X_{ivd}) \leq UCAP_d Z_d \quad \forall\ d$
$\Sigma_{iv}(BRDN_{id}X_{ivd}) \geq LCAP_d Z_d \quad \forall\ d$

4) $\Sigma_d(FCST_d Z_d) \leq BUDGET$

5) $Q_{idc} \leq Z_d \quad \forall\ i,d,c$

6) $\Sigma_v X_{ivd} \geq \Sigma_c Y_{idc} \quad \forall\ i,d$

7) $Y_{idc} \leq DEM_{i,c}\ Q_{idc} \quad \forall\ i,d,c$
$\Sigma_d Q_{idc} = 1 \quad \forall\ i,c$

CONSTRAINT EXPLANATION

1) Demand can not exceed supplier's capacity.

2) All customer demand must be met.

3) For each depot, throughput must not exceed depot capacity. Since handling of appregate products is not uniform, a burden rate is determined for each aggregate product.

4) The fixed cost of operating depots must remain within budgetary constraints.

5) This constraint ensures that "sole sourcing" a customer zone assignments can only be made to open depots.

6) This is the flow balance constraint.

7) Customers are sole sourced for each product to a specific depot.

APPENDIX B

Table B1. Represents the sixty-eight FSC product groupings managed by DLA

FSC PRODUCT GROUP	DESCRIPTION	FSC PRODUCT GROUP	DESCRIPTION
10	Weapons	53	Hardware & Abrasive
12	Fire Control Equip	54	Prefabricated Structures & Scaffolding
14	Guided Missiles Equip	55	Lumber, Millwork, Plywood, & Veneer
15	Acft & Airframe Structural Comps	56	Construction & Building Materials
16	Acft Comps & Accessories	58	Communication Equip
17	Acft Launcing, Ldg,&Gnd Handling	59	Electrical & Electronic Equip/Comp
20	Ship & Marine Equip	60	Fiber Optics Matls, Comps, Assys
22	Railway Equip	61	Electric Wire & Power & Dist
24	Tractors	62	Lighting Fixtures & Lamps
25	Vehicular Equip Components	63	Alarm & Signal Systems
26	Tires	65	Medical, Dental, & Veterinary Equip
28	Engines, Turbines, & Comps	66	Instruments & Laboratory Equip
29	Engine Accessories	67	Photographic Equip
30	Mechanical Power Transmission	68	Chemicals & Chemical Products
31	Bearings	69	Training Aids & Devices
32	Woodworking Machinery & Equip	70	General Purpose ADPE, Software
34	Metalworking Machinery	~~71~~	Furniture
35	Service & Trade Equip	72	Household & Coml Furnishings
36	Special Industry Machinery	73	Food Preparation & Serving Equip
37	Agricultural Machinery & Equip	74	Office Machines, Visible Record Equip
38	Construction, Mining, Excavating	75	Office Supplies & Devices
39	Materials Handling Equip	76	Books, Maps, & Other Publications
40	Rope, Cable, Chain, & Fittings	79	Cleaning Equip & Supplies
41	Refrigeration & Air Cond Equip	80	Brushes, Paints, Sealers, & Adhesives
42	Fire Fighting, Rescue & Safety Equip	81	Containers, Packaging, & Packing Supplies
43	Pumps & Compressors	83	Textiles,Leather,Furs, Notions, Yarn, Tents
44	Furnace, Steam, Plant, Drying Equip	84	Clothing & Individual Equip
45	Plumbing, Heating, & Sanitation Equip	~~85~~	Toiletries
46	Water Purification & Sewage Treat	~~89~~	Subsistence
47	Pipe, Tube, & Hose	91	Fuels, Lubricants, Oils, & Waxes
48	Valves	93	Nonmetallic Fabricated Materials
49	Maintenance & Repair Shop Equip	95	Metal Bars, Sheets & Shapes
51	Hand Tools	~~96~~	Ores, Minerals, & their Primary Products
52	Measuring Tools	99	Miscellaneous

Table B2. Represents a detailed breakdown of the product classes available in FSC product group 53.

FSC	Description
5305	Screws
5306	Bolts
5307	Studs
5310	Nuts & Washers
5315	Nails, Keys & Pins
5320	Rivets
5325	Fastening Devices
5330	Packing & Gasket Materials
5335	Metal Screening
5340	Miscellaneous Hardware
5345	Disks & Stones Abrasive
5350	Abrasive Materials
5355	Knobs & Pointers
5360	Coil, Flat, & Wire Springs
5365	Rings, Shims & Spacers

APPENDIX C

Table C1. Listing of FSC's represented in the material release order files for FY 92. Additionally, this table provides the mean unit wt standard deviation, mean extended weight (requisition quantity multiplied by unit weight), and standard deviation extended weight.

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1005	Guns thru 30 MM	52976	1.09	3.53	41.01	506.66
1010	Guns Over 30 MM Up To 75 MM	4009	1.44	1.48	20.38	159.9
1015	Guns 75 MM Thru 125 MM	6655	4.08	7.47	25.43	295.3
1020	Guns Over 125 MM Thru 150 MM	2505	2.47	7.14	8.47	53.13
1025	Guns Over 150 MM Thru 200 MM	3887	4.62	8.66	29.93	151.66
1030	Guns Over 200 MM Thru 300 MM	27	1.02	1.44	3.25	6.35
1035	Guns Over 300 MM	58	2.95	0.46	12.55	13.71
1040	Chemical Weapons and Equip	468	1.38	0.83	4.99	17.75
1045	Launchers Torpedo & Depth Charge	442	1.89	0.19	9.31	24.87
1055	Launchers Torpedo & Pyrotechnic	1548	1.86	1.79	15.43	98.7
1075	Degaussing & Mine Sweeping Equip	163	1.93	0.45	51.06	312.32
1080	Camouflage & Deception Equip	223	1.88	0	108.87	248.39
1090	WPNS Assy Interchange	358	6.19	8.39	27.45	80.62
1095	Miscellaneous Weapons	3545	1.3	2.03	34.72	266.41
1210	Fire Control Directors	23	2.19	1.74	3.26	3.08
1220	Fire Control Computing Sights & Devices	367	0.9	0.69	5.26	12.85
1240	Optical Sighting & Ranging Equip	3587	1.35	5.91	9.21	48.99
1250	Fire Control Stabilizing Mechanisms	1	1.64		9.84	
1260	Fire Cntl Designating-Indicating Equip	287	0.14	0.11	0.9	1.89
1265	Fire Control Equip Except Airborne	83	1.31	0.51	2.56	3.51
1270	Aircraft Gunnery Fire Control Comps	978	0.53	0.3	2.98	8.99
1280	Aircraft Bombing Fire Control Comps	447	0.24	0.15	0.97	2.55
1285	Fire Control Radar Equip Except Air	1038	3.01	7.07	8.73	26.3
1287	Fire Control Sonar Equip	7	1.46	0	1.46	0
1290	Miscellaneous Fire Control Equi	2011	0.81	1.23	4.24	12.13
1420	Guided Missile Components	643	1.8	4.28	17.85	71.54
1430	Guided Missile Remote Control Systems	3089	1.65	3.31	11.32	42.36
1440	Launchers Guided Missile	5830	1.85	2.77	13.27	55.92
1450	Guided Missile Handling Servicing Equip	1326	6.05	9.52	31.1	107.41
1560	Airframe Structural Comps	125447	3.48	8.47	13.98	77.31
1610	Aircraft Propellers	2052	2.11	4.12	12.03	88.06
1615	Helicopter Rotor Blades-Drive Mech	13964	1.19	3.33	7.09	35.93
1620	Aircraft Landing Gear Comps	5325	2.18	6.83	15.8	179.48
1630	Aircraft Wheel & Brake Systems	7470	2.15	4.08	22.02	113.49
1650	Aircraft Hydraulic Vacuum De-icing Comps	29875	1.38	14.51	8.99	83.87
1660	Aircraft Air Conditioning Heating Equip	10744	0.63	0.67	3.61	13.86
1670	Parachutes Recovery Sys & Tie Down Equip	6810	4.12	8.9	144.36	861.92
1680	Misc Aircraft Accessories Comps	51299	1.33	6.29	7.62	63.3
1710	Aircraft Arresting Barrier & Equip	617	12.17	0.49	59.28	144.64
1720	Aircraft Launching Equip	112	12.21	0.66	230.79	835.45
1730	Aircraft Ground Servicing Equip	22445	12.36	35.4	62.1	307.12
1740	Airfield Specialized Trucks & Trailers	1690	19.64	44.41	123.38	720.22
2010	Ship & Boat Propulsion Comps	3020	26.57	50.96	163.55	1412.77
2020	Rigging & Rigging Gear	46	16.35	9.31	97.86	167.74
2030	Deck Machinery	1253	6.48	12.29	19.13	56.17
2040	Marine Hardware & Hull Items	8197	21	89.48	469.33	15390.63
2050	Buoys	33	6.75	2.78	366.86	1185.81
2090	Miscellaneous Ship & Marine Equip	3906	36.33	51.79	1343.58	65179.97
2240	Locomotive & Rail Car Accessories	127	21.82	18.39	355.76	727.82
2250	Track Materials Railroad	37	8.19	15.69	1309.66	1626.87
2410	Tractors Full Track Low Speed	19	85.49	167.23	165.19	278.2
2420	Tractors Wheeled	15	11.5	15.61	11.56	15.56
2510	Vehicular Cab Body Frame Structural Comp	147898	22.06	38.63	55.21	432.38
2520	Vehicular Power Transmission Comps	80748	11.53	36.06	56.02	662.87
2530	Vehicular Brake Steering Axle Wheel Comp	204992	11.92	47.08	52.42	3277.37
2540	Vehicular Furniture & Accessories	311445	8.68	21.89	28.09	350.68
2590	Miscellaneous Vehicular Comps	97477	8.39	27.43	29.63	338.48
2620	Tires & Tubes Pneumatic Aircraft	1891	14.95	11.51	50.37	117.03
2805	Gas Reciprocating Engine-Except Aircraft	18910	14.35	41.9	81.18	762.06
2810	Gas Reciprocating Eng-Aircraft &Comps	402	1.43	3.19	1198.08	7754.09
2815	Diesel Engines & Comps	44394	16.21	53.1	99.24	698.85
2820	Steam Engines Reciprocating & Comps	9	5.26	4.75	6.37	6.74
2825	Steam Turbines & Comps	5320	7.44	44.82	16.4	105.06
2830	Water Turbines-Water Wheels & Comps	1	27		108	
2835	Gas Turbines & Jet Eng Except Aircraft	6293	3.19	9.63	32.67	349.44
2840	Gas Turbines & Jet Engines Aircraft	17719	0.68	1.96	37.84	773.91
2850	Gasoline Rotary Engines & Comps	1	20.85		1042.7	
2895	Miscellaneous Engines & Comps	174	3.4	11.03	4.63	11.76
2910	Engine Fuel Sys Components Nonaircraft	128847	3.11	13.33	12.5	115.97
2915	Engine Fuel Systems Components Aircraft	6924	1.27	6.85	12.47	143.96

Table C1. Continued

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
2920	Engine Electrical Sys Comps Nonaircraft	111521	4.29	10.48	13.79	99.01
2925	Engine Electrical Sys Comps Aircraft	4573	0.62	0.96	15.05	355.58
2930	Engine Cooling Sys Comps-Nonaircraft	35072	14.6	38.88	51.03	652.91
2935	Engine Cooling Sys Comps-Aircraft	891	18.9	47.52	1951.33	43045.9
2940	Engine Air & Oil Filters - Nonaircraft	119112	3.7	7.3	23.5	308.24
2945	Engine Air & Oil Filters - Aircraft	2534	0.37	0.59	4.96	42.1
2950	Turbosuperchargers	531	15.55	15.43	48.22	144.49
2990	Misc Engine Accessories-Nonaircraft	62069	9.53	14.46	30.33	1113.35
2995	Misc Engine Accessories-Aircraft	6166	0.77	2.03	3.57	15.68
3010	Torque Converters & Speed Changers	17687	18.67	44.55	47.29	236.43
3020	Gears Pulleys Sprockets & Trans Chain	48482	4.79	19.13	27.6	703.15
3030	Belting Drive Belts Fan Belts & Access	77856	3.13	14.7	24.88	983.99
3040	Miscellaneous Power Transmission Equip	90883	7.31	29.18	27.58	611.03
3110	Bearings Antifriction Unmounted	179900	1.57	7.91	16.1	280.41
3120	Bearings Plain Unmounted	151535	0.99	33.95	12.12	897.52
3130	Bearings Mounted	5632	4.17	8.04	27.07	256.11
3210	Sawmill & Planing Mill Machinery	8	1.26	2.55	4.27	9.81
3220	Woodworking Machines	343	153.57	302.27	179.6	380.68
3230	Tools - Attachments For Woodworking Mach	2303	0.98	1.57	10.15	43.3
3405	Saws & Filing Machines	125	72.01	287.21	87.79	296.66
3413	Drilling & Tapping Machines	237	286.92	194.54	329.69	289
3415	Grinding Machines	889	57.8	70.77	80.21	121.04
3416	Lathes	26	46.59	117.47	205.79	819.23
3417	Milling Machines	239	20.28	68.5	37.19	103.43
3419	Miscellaneous Machine Tools	172	78.1	177.14	252.06	1416.74
3424	Metal Heat Treating Equip	11	437.3	359.84	629.38	602.62
3426	Metal Finishing Equip	328	8.85	40.54	39.21	149.27
3431	Electric Arc Welding Equip	4614	17.01	86.5	45.08	367.35
3432	Electric Resistance Welding Equip	70	39.14	75.94	47.7	79.82
3433	Gas Welding Heat Cutting-Metalizing Equip	5470	4.79	13.09	14.39	116.2
3436	Welding Positioners & Manipulators	33	112.28	91.6	162.93	194.59
3438	Miscellaneous Welding Equip	193	32.5	10.83	66.18	78.39
3439	Misc Welding soldering & Brazing Supply	58554	2.55	7.27	68.02	910.5
3441	Bending & Forming Machines	302	176.69	402.33	277.67	1121.94
3442	Hydraulic & Pneumatic Presses Power Dr	14	135.61	283.59	135.89	283.45
3443	Mechanical Presses Power Driven	12	3.16	5.63	6.68	7.54
3444	Manual Presses	207	470.18	516.23	552.48	689.92
3445	Punching & Shearing Machines	220	45.23	82.79	113.42	397.4
3446	Forging Machinery & Hammers	21	55.97	139.73	56.59	139.48
3448	Riveting Machines	12	3.33	10.29	3.55	10.23
3449	Misc Secondary Metal Forming-Cutting Mach	170	50.89	34.15	521.1	1675.51
3450	Machine Tools portable	57	69	32.32	76.28	45.39
3455	Cutting Tools For Machine Tools	23613	0.83	2.63	14.7	448.39
3456	Cutting Tools For Secondary Metal Mach	434	1.82	5.65	6	26.47
3460	Machine Tool Accessories	10234	3.15	12.24	28.56	218.81
3465	Production Jigs Fixtures & Templates	718	0.19	0.4	2.06	6.86
3510	laundry & Dry Cleaning Equip	1937	11.68	68.96	58.56	271.72
3520	Shoe Repairing Equip	11	152.16	337.61	153.19	337.1
3530	Industrial Sewing Machine & Mobile Textile	1510	60.68	148.34	78.58	220.07
3540	Wrapping & Packaging Machinery	83	19.11	9.57	58.12	83.09
3590	Miscellaneous Service & Trade Equip	30	0.68	0	1.16	1.63
3610	Printing Duplicating & Bookbinding Equip	2062	31.58	68.5	194.5	1967.46
3611	Industrial Marking Machines	274	4.53	17.2	7.82	24.11
3615	Pulp & Paper Industries Machinery	76	42.08	80.27	326.66	1420.95
3625	Textile Industries Machinery	1	300	.	300	.
3630	Clay-Concrete Products Industries Mach	1	29.44	.	412.2	.
3635	Crystal & Glass industries Machinery	13	473	0	473	0
3650	Chemical & Pharmaceutical Machinery	7	16.79	43.31	16.85	43.28
3655	Gas Generating & Dispensing System	1959	6.95	22.68	15.69	62.66
3660	Industrial Size Reduction Machinery	4	1.3	0	4.55	5.67
3670	printed Circuit Board MFG Mach	1	385.01	.	1155.03	.
3680	Foundry Machinery - Related Equip & Sup	90	29.89	39.46	817.18	3038.27
3685	Specialized Metal Container Mfg Mach	2	43	0	150.5	152.03
3693	Industrial Assembly Machines	6	1.5	0.55	1.83	0.41
3694	Clean Work Stations Environment Equip	233	31.61	130.53	102.4	203.77
3695	Miscellaneous Special Industry Machinery	566	14.4	20.29	29.09	61.04
3710	Soil Preparation Equip	24	95.67	148.05	248.17	214.94
3740	pest Disease & Frost Control Equip	1561	36.43	149.91	95.19	410.32
3770	Saddlery Harness Whips & Furnishings	604	0.84	0.86	7.1	14.74
3805	Earth Moving & Excavating Equip	2067	73.89	178.21	365.79	1480.02

Table C1. Continued

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
3810	Cranes & Crane-Shovels	703	16.24	37.48	35.23	170.36
3815	Crane & Crane-Shovel Attachments	491	129.85	341.2	267.55	628.51
3820	Mining Rock Drilling Earth Boring Equip	1258	26.64	60.85	62.21	137.25
3825	Road Clearing & Cleaning Equip	1727	53.47	149.36	635.24	5068.78
3830	Truck & Tractor Attachments	3785	78.26	201.67	283.03	1304.19
3835	Petroleum Production-Distribution Equip	80	14.28	69.24	567.05	4860.02
3895	Misc Construction Equip	3011	31.13	106.82	72.65	274.89
3910	Conveyors	811	51.85	76.48	617.02	3127.8
3920	Matl Handling Equip - Nonself Prop	2515	120.17	179.44	496.61	2837.55
3930	Warehouse Trucks & Tractors Self-Prop	4242	29.24	85.13	45.6	147.6
3940	Blocks Tackle Rigging & Slings	3732	57.66	132.09	200.05	835.21
3950	Winches Hoists Cranes & Derricks	4363	63.62	167.3	157.7	833.93
3960	Elevators & Escalators	164	25.03	15.47	268.47	571.24
3990	Misc Materials Handling Equip	3301	66.21	186.54	5078.94	56542.83
4010	Chain & Wire Rope	48401	59.55	199.85	617.43	55277.55
4020	Fiber Rope Cordage & Twine	27177	54.62	138.43	326.41	4651.8
4030	Fittings For Rope Cable & Chain	47078	4.86	16.29	42.6	387.04
4110	Refrigeration Equip	3374	316.71	345.51	812.85	7335.48
4120	Air Conditioning Equip	1058	154.2	131.58	912.24	2376.8
4130	Refrigeration & Air Conditioning Comp	27703	15.25	65.44	134.2	9845.78
4140	Fans Air Circulators & Blower Equip	20630	11.58	54.66	44.85	1508.05
4210	Fire Fighting Equip	30807	20.42	47.9	331.34	3602.22
4220	Marine Lifesaving & Diving Equip	12475	6.48	50.53	77.23	703.97
4230	Decontaminating & Impregnating Equip	1087	8.31	12.28	83.34	925.95
4240	Safety & Rescue Equip	43534	2.93	12.06	52.51	566.9
4310	Compressors & Vacuum Pumps	21510	15.78	72.33	49.43	417.45
4320	Power & Hand Pumps	51630	12.04	53.51	48.3	3848.7
4330	Centrifugals, Separators, & Filters	74429	3	9.41	26.81	288.33
4410	Industrial Boilers	1540	52.48	157.17	353.25	3009.19
4420	Heat Exchangers & Steam Condensers	1134	67.73	139.68	138.82	306.94
4430	Industrial Furnaces Kilns Lehrs & Ovens	95	106	207.17	140.73	227.76
4440	Driers Dehydrators & Anhydrators	7008	11.21	37.04	88.39	2443.83
4460	Air Purification Equip	1379	10.89	50.96	216.71	1426.5
4510	Plumbing Fixtures & Accessories	20392	8.66	25.18	112.28	720.87
4520	Space Heating Equip & Water Heaters	13924	25.18	121.56	110.16	465.6
4530	Fuel Burning Equip Units	4131	4.46	14.41	24.07	96.11
4540	Misc Plumbing Heating & Sanitation Equip	10558	11.02	39.5	54.11	378.88
4610	Water Purification Equip	3048	21.7	61.04	213.98	1066.09
4620	Water Distillation Equip Marine & Industrial	534	9.43	20.83	28.2	57.34
4630	Sewage Treatment Equip	216	7.79	10.88	11.72	15.78
4710	Pipe & Tube	109665	4.41	30.38	263.81	8003.25
4720	Hose & Tubing Flexible	237074	3.93	22.65	77.72	13671.49
4730	Fittings Hose Pipe & Tube	596486	0.7	5.52	8.73	192.25
4810	Valves Powered	22153	6.4	40.57	14.81	94.34
4820	Valves Non-Powered	192587	5.25	27.31	24.85	881.28
4910	Motor Vehicle Maintenance Equip	24236	17.22	59.35	74.83	1027.56
4920	Aircraft Maint & Repair Shop Equip	8368	7.71	13.37	44.37	267.37
4921	Torpedo Maint Repair & Checkout Equip	73	6.37	0	68.52	181.49
4925	Ammunition Maintenance Checkout Equip	25	2.34	1.03	10.62	18.45
4930	Lubrication & Fuel Dispensing Equip	30539	8.49	22.15	33.1	933.38
4931	Fire Control maintenance Equip	919	1.06	1.09	4.59	19.22
4933	Weapons Maintenance Equip	1914	2.19	4.51	22.51	538.88
4935	Guided Missile Maintenance Equip	1965	0.88	0.68	6.5	29.62
4940	Misc Maintenance Equip	10954	17.37	42.81	111.12	512.32
5110	Hand Tools Edged Nonpowered	176	0.94	1.84	5.44	17.14
5120	Hand Tools NonEdged Nonpowered	1453	0.67	0.63	2.6	5.66
5130	Hand Tools Power Driven	11	7.47	3.6	20.72	35.88
5133	Drill Bits Counterbores & Countersinkd	1	1.29	.	1.29	.
5140	Tool & Hardware Boxes	103	1.29	0	4.17	5.94
5180	Sets Kits & Outfits of Hand Tools	15	1.29	0	2.15	1.35
5210	Measuring Tools Craftmens	21	1.58	1.23	2.94	3.83
5220	Inspection Gauges & Precision Layout	1582	2.34	5.17	8.81	53.66
5280	Sets Kits & Outfits of Measuring Tools	2	2.31	0	3.46	1.63
5305	Screws	587830	0.5	1.68	10.87	431.5
5306	Bolts	355154	0.49	2.85	8.2	107.05
5307	Studs	31394	0.38	1.63	14.02	169.24
5310	Nuts & Washers	692389	0.38	9.3	8.16	373.71
5315	Nails Keys & Pins	243988	0.66	7.61	10.77	487.65
5320	Rivets	202492	0.28	2.49	10.23	575.33
5325	Fastening Devices	102953	0.14	0.48	2.99	51.86

Table C1. Continued

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
5330	Packing & Gasket Materials	1092186	0.72	12.53	4.38	125.01
5335	Metal Screening	1411	34.34	85.84	286.54	1268.24
5340	Misc Hardware	663263	1.16	5.41	13.3	306.71
5345	Disks & Stones Abrasive	27	1.21	0.24	6.96	5.87
5350	Abrasive Matls	38	32.87	21.15	43.14	34.63
5355	Knobs & Pointers	60982	0.09	0.41	0.45	2.59
5360	Coil, Flat, & Wire Springs	124330	0.38	3.51	3.19	51.75
5365	Rings, Shims, & Spacers	232751	0.23	4.66	2.62	85.76
5410	Prefabricated & Portable Building	840	20.58	48.48	146.26	733.53
5411	Rigid Wall Shelters	194	0.41	1.13	1.09	1.82
5420	Bridges Fixed & Floating	891	23.77	28.93	694.96	5196.03
5430	Storage Tanks	1011	14.66	59.59	49.85	275.87
5440	Scaffolding Equip & Concrete Forms	1894	45.27	41.24	127.86	209.6
5445	Prefabricated Tower Structures	26	35.7	17.08	94.52	84.91
5450	Misc Prefabricated Structures	1137	97.87	444.71	1565.37	7797.31
5510	Lumber & Related Basic Wood Matls	4224	6.38	18.62	12068.08	95848.73
5520	Millwork	2	68.49	0	1369.7	484.26
5530	Plywood & Veneer	203	44.54	10.49	4579.06	24561.26
5660	Fencing Fences & Gates	1916	52.23	72.38	4236.92	25450.31
5680	Misc Construction Matl	3	1566.79	1372.71	190206.92	284375.9
5805	Telephone &Telegraph Equip	13001	3.22	7.45	50.12	332.22
5810	Communications Security Equip	210	2.05	0.02	11.27	19.16
5811	Other Cryptologic Equip & Comps	55	2.05	0.04	5.2	8.25
5815	Teletype & Facsimile Equip	5739	0.43	1.75	2.97	16.5
5820	Radio TV Equip Except Airborne	4277	5.48	11.12	39.95	218.09
5821	Radio TV Equip Airborne	1027	0.54	1.83	5.29	57.08
5825	Radio Navigation Equip- Non Airborne	163	7.25	16.2	15.61	29.31
5826	Radio Navigation Equip- Airborne	1233	0.38	0.5	1.61	6.83
5830	Intercomm Public Address Sys-Non	615	8.68	9.32	19.5	25.83
5831	Intercomm Public Address Sys-Air	265	0.79	1.36	2.93	9.05
5835	Sound Recording & Reproducing Equip	2797	1.61	3.88	107.36	1012.33
5836	Video Recording & Reproducing Equip	2794	1.08	1.23	50.23	153.66
5840	Radar Equip Except Airborne	1592	2.97	3.17	63.11	1329.32
5841	Radar Equip Airborne	2174	0.58	0.6	3.54	20.2
5845	Underwater Sound Equip	1156	0.96	0.88	26.95	477.59
5850	Visible/Invisible Light Com Equip	344	3.19	4.65	12.72	29.01
5855	Night Vision Equip	8241	0.8	1.38	6.51	20.89
5860	Stimulated Coherent Radiation Devices	113	1.48	1.01	3.87	8.59
5865	Elect Countermeasures & Quick React	1390	0.67	0.55	5.85	18.93
5895	Misc Communication Equip	14061	1.87	5.89	14.54	116.18
5905	Resistors	234163	0.15	2.05	1.59	42.1
5910	Capacitors	117521	0.17	1.87	1.37	15.45
5915	Filters & Networks	25293	1.12	4.79	4.04	127.31
5920	Fuses & Lightning Arresters	148148	0.2	1.68	3.66	26.27
5925	Circuit Breakers	54617	1.34	5.7	6.6	217.43
5930	Switches	274678	0.56	3.12	2.42	111.98
5935	Connectors Electrical	458505	0.23	7.18	3.83	220.95
5940	Lugs Terminals & Terminal Strips	136432	0.57	2.52	12.07	1069.14
5945	Relays & Solenoids	116379	0.74	1.87	2.79	35.39
5950	Coils & Transformers	60876	3.73	21.19	10.84	123.06
5955	Piezoelectric Crystals	11361	0.2	2.57	0.73	3.92
5960	Electron Tubes & Assoc Hardware	35840	2.22	7.52	14.92	1061.51
5961	Semiconductor Devices & Assoc Hardware	190721	0.08	0.26	1.46	47.26
5962	Microcircuits - Electronics	166526	0.11	14.61	0.78	45.34
5963	Electronic Modules	3691	0.31	2.84	1.92	58.59
5965	Headsets Handsets Microphones & Speakers	42940	2.35	7.61	16.09	131.69
5970	Elec Insulators & Insulating Matl	83128	1.38	9.54	25.36	800.52
5975	Electrical Hardware & Supplies	126587	2.35	10.95	54.33	384.77
5977	Electrical Contact Brushes & Electrodes	19835	0.41	4.07	8.15	202.66
5980	Optoelectronic Devices & Assoc Hardware	12440	0.07	0.02	0.98	7.91
5985	Antennas Waveguides & Related Equip	59834	2.33	9.43	9.26	63.55
5990	Synchros & Resolvers	7568	1.07	2.04	8.62	459.91
5995	Cable Cord wire Assemblies- Comm Equip	90934	1.56	3.96	8.41	60.6
5998	Misc Electrical Equip	30532	0.69	1.2	2.46	19.61
5999	Misc Electronic Components	104984	0.25	1.18	8.7	187.88
6015	Fiber Optic Cables	5	0.01	0	5.55	8.18
6020	Fiber Optic Cable Assy & Harness	167	0.08	0.05	0.34	0.78
6025	Fiber Optic	6	0.53	0	15.34	11.34
6026	Fiber Optic	14	0.53	0	4.64	2.98
6030	Fiber Optic Devices	16	0.99	1.78	1.66	3.21

Table C1. Continued

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
6035	Fiber Optics	4	0.53	0	2.93	0.92
6050	Fiber Optics	1	0.53	.	4.26	.
6060	Fiber Optics Interconnectors	145	0.15	0.32	12.73	46.74
6070	Fiber Optics Accessories & Supplies	24	0.1	0.02	0.66	0.63
6080	Fiber Optics Kits & Sets	3	0.53	0	28.37	44.57
6099	Fiber Optics Misc	1	0.53	.	1.06	.
6105	Motors Electrical	24596	12.3	61.5	99.59	7020.82
6110	Electrical Control Equip	13218	8.14	79.56	38.98	1132.41
6115	Generators & Generator Sets Elect	7484	19.06	56.82	44.89	316.78
6120	Transformers - Distribution & Power Sta	572	119.15	164.05	306.97	784.51
6125	Converters Electrical Rotating	626	9.03	21.21	49.75	258.35
6130	Converters Electrical Nonrotating	13690	8.26	21.58	20.68	114.13
6135	Batteries Primary	33356	1.8	2.36	84.31	1219.17
6140	Batteries Secondary	41672	16.97	27.3	113.79	4108.51
6145	Wire & Cable Electrical	116221	3.13	15.73	454.3	17657.85
6150	Misc Electric Power & Distribution Equip	50999	9.12	29.69	33.14	319.95
6160	Misc Electric Power	4066	3.08	0.12	9.62	20.02
6210	Indoor & Outdoor Elec Lighting Fixtures	81100	1.16	5.29	25.61	1424.79
6220	Electric Vehicular Lights & Fixtures	109194	1.37	2.61	7.02	315.15
6230	Electric portable & Hand Lighting Equip	30866	4.81	11.74	56.7	408.29
6240	Electric Lamps	207790	0.42	1.39	25.35	423.62
6250	Ballasts Lampholders & Starters	13307	1.48	3.6	29.95	128.93
6260	Nonelectrical Lighting Fixtures	21331	1.04	1.66	33.67	104.68
6310	Traffic & Transit Signal Systems	9	2.74	1.7	2.74	1.7
6320	Shipboard Alarm & Signal Systems	434	12.33	20.65	35.15	262.04
6340	Aircraft Alarm & Signal Systems	2775	0.52	1.01	2.07	13.78
6350	Misc Alarm & Signal Systems	13159	2.49	6.03	15.56	444.2
6505	Drugs Biological & Official Reagents	636990	1.57	5.6	59.67	1968.97
6508	Medicated Cosmetics & Toiletries	3997	3.99	8.77	120.63	707.38
6510	Surgical Dressing Materials	79220	2.91	5.12	58.33	370.36
6515	Medical Surgical Instruments Equip & Sup	266777	1.89	4.97	57.9	832.93
6520	Dental Instruments Equip & Supplies	114281	1.79	10.01	18.04	500.62
6525	X-Ray Equip Supplies - Medical & Dental	4893	42.35	355.33	603.86	11104.51
6530	Hospital Furniture Equip Utensils & Supply	59901	14.35	32.93	228.59	1813.87
6532	Hospital & Surgical Clothing	11953	7.83	10.53	141.86	1047.2
6540	Opticians Instruments Equip & Supplies	53573	0.69	7.16	19.18	230.61
6545	Medical Sets Kits & Outfits	14529	41.83	235.51	549.43	2705.44
6550	In Vitro Diagnostic Substances, Reagents	16717	1.56	6.46	24.27	414.41
6605	Navigational Instruments	4709	1.6	10.63	11.2	62.38
6610	Flight Instruments	5846	0.56	3.01	4.66	35.71
6615	Automatic Pilot Mechanisms Airborne Gyro	2684	0.43	1.19	4.42	35.73
6620	Engine Instruments	22845	0.64	2.34	3.81	53.04
6625	Electrical Electromic Measuring Instrument	78332	0.86	5.1	3.48	38.77
6630	Chemical Analysis Instruments	12899	2.27	5.07	25.81	113.79
6635	Physical Properties Testing Equip	5187	6.55	30.35	15.48	90.97
6640	Laboratory Equip & Supplies	28428	3.92	18.33	93.1	4445.31
6645	Time Measuring Instruments	16720	0.88	2.32	3.27	16.63
6650	Optical Instruments	7256	1.07	3.95	5.49	23.98
6655	Geophysical & Astronomical Instruments	391	1.09	1.61	130.08	1208.2
6660	Meteorological Instruments & Apparatus	3591	1.34	4.92	22.01	244.32
6665	Hazard-Detecting Instruments & Apparatus	9503	2.16	1.61	16.89	59.59
6670	Scales & Balances	3376	23.92	46.06	60.45	247.41
6675	Drafting Surveying & Mapping Instruments	8237	5.59	23.22	16.14	163.54
6680	Liquid Gas Motion Measuring Instruments	62395	1.94	7.85	6.57	193.08
6685	Pressure Temp Humidity Instruments	77648	1.44	7.74	8.01	296.25
6695	Combination & Misc Instruments	6302	2.67	8.94	7.67	42.61
6710	Cameras Motion Picture	153	1.26	1.77	21.15	90.54
6720	Cameras Still Picture	635	1.52	3.09	7.91	23.35
6730	Photographic Projection Equip	2805	15.51	25.26	37.41	75.8
6740	Photo Developing & Finishing Equip	1725	3.48	15.76	20.22	182.83
6750	Photographic Supplies	24647	9.47	41.2	150.68	1269.61
6760	Photographic Equip & Accessories	2027	2.16	4.59	24.09	140.39
6770	Film Processed	18	0.6	0.49	1.95	2.25
6780	Photographic Sets Kits & Outfits	92	14.74	12.8	85.91	269.47
6810	Chemicals	39391	37.61	89.37	906.02	6780.66
6820	Dyes	131	7.47	23.33	37.12	82.26
6830	Gases Compressed & Liquefied	4135	44.97	64.97	2048.15	90132.34
6840	Pest Control Agents & Disinfectants	13113	11.89	40.27	231.99	1771.31
6850	Misc Chemical Specialities	55671	67.27	156.72	717.8	4704.71
6910	Training Aids	831	5.31	8.3	57.43	362.21

Table C1. Continued

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
6920	Armament Training Devices	1783	10.91	58.73	235.31	4531.84
6930	Operational Training Devices	341	1.98	12.93	5.55	18.01
6940	Communication Training Devices	85	0.52	0.36	3.65	7.94
7010	ADPE Configuration	1167	2.17	5.1	3.87	9.4
7020	ADP Central Processing Unit - Analog	137	4.79	0.99	14.68	15.85
7021	ADP Central Processing Unit - Digital	158	0.33	0.29	0.78	1.07
7025	ADP Central Processing Unit - Hybrid	6081	2.27	4.67	18.81	125.41
7030	ADP Input/Output & Storage Devices	66	4.29	2.45	37.31	69.17
7035	ADP Software	1471	0.78	1.44	3.47	18.14
7040	ADP Support Equip	194	0.7	0.56	25.25	83.33
7045	ADP Supplies & Support Equip	14625	1.44	3.4	54.44	338.75
7050	ADP Components	1475	2.09	2.35	5.42	17.19
7105	Household Furniture	5822	16.78	18.71	854.53	9119.11
7110	Office Furniture	880	81.02	27.42	708.76	3387.62
7125	Cabinets Lockers Bins & Shelving	1359	242.08	90.2	886.25	1938.03
7195	Misc Furniture & Fixtures	63	65.04	54.39	607.37	1608.72
7210	Household Furnishings	13634	7.37	12.74	895.61	6935.4
7240	Household & Commercial Util Containers	8548	6.07	4.53	149.99	720
7290	Misc Household Furnishings Appliances	723	3.09	0	59.77	107.18
7310	Food Cooking Baking Serving Equip	25372	30.85	102.26	104	694.62
7320	Kitchen Equip & Appliances	6386	79.91	245.37	179.93	637.59
7330	Kitchen Hand Tools & Utensils	2033	13.85	10.99	537.99	8759.54
7340	Cutlery & Flatware	2326	0.17	0.13	11.55	32.83
7350	Tableware	1305	1.59	3.47	62.58	486.33
7360	Sets Kits & Outfits Food Prep & Serving	6351	14.31	30.13	68.55	300.96
7430	Typewriters & Office Type Composing	58	97.27	0	405.85	541.47
7450	Office Type Sound Recording Repro Mach	54	2.25	3.5	3.76	5.16
7460	Visible Record Equip	42	11.05	28.32	30.19	97.37
7510	Office Supplies	505	3.21	57.7	9.01	115.56
7520	Office Devices & Accessories	1123	0.55	0.75	10.32	40.06
7530	Stationery & Record Forms	1725	91.04	326.14	806.86	3521.28
7540	Standard Forms	156	0.6	0.06	15.43	43.95
7610	Books & Pamphlets	999	4.12	9.84	25.21	62.08
7630	Newspapers & Periodicals	1	3	.	3	.
7640	Maps Atlases Charts & Globes	52	0.46	0.8	6.92	23.34
7670	Microfilm Processed	2	0.34	0	0.34	0
7690	Misc Printed Matter	20899	0.22	0.79	6.45	279.6
7910	Floor Polishers & Vacuum Cleaners	154	74.41	6.48	563.08	1916.67
7920	Brooms Brushes Mops & Sponges	361	1.12	3.3	11.78	97.72
7930	Cleaning - Polishing Compounds & Preps	197	33.68	14.51	141.87	454.52
8020	Paint & Artists Brushes	52	2.75	0	17.17	23.27
8030	Preservative & Sealing Compounds	9	2.75	0	22.96	28.5
8040	Adhesives	18	2.48	0.8	7.85	6.91
8105	Bags & Sacks	2091	12.09	11.1	822.68	12017.78
8110	Drums & Cans	8788	49.45	54.71	1128.36	3321.65
8115	Boxes Cartons & Crates	1480	37.99	47.76	159.1	291.39
8120	Gas Cylinders	4479	62.43	64.51	1004.22	6846.9
8125	Bottles & Jars	3482	4.2	4.98	50.58	136.23
8130	Reels & Spools	302	19.53	29.44	206.33	714.69
8135	Packaging & Packing Bulk Materials	45	7.37	8	796.08	3217.61
8140	Ammunition & Nuclear Ordnance Boxes	4471	1.72	7.9	33.62	517.21
8145	Specialized Shipping & Storage Container	288	11.04	51.4	250.14	592.6
8305	Textile Fabrics	21514	2.31	17.79	3581.07	186982
8310	Yarn & Thread	2734	2.18	8.31	14.94	67.47
8315	Notions & Apparel Findings	21453	0.4	1.69	48.32	372.51
8320	Padding & Stuffing Materials	35	3.33	4.57	5735.96	11288.85
8330	Leather	1165	1.42	1.61	49.5	183.25
8335	Shoe Findings & Soling Materials	2930	0.8	3.67	15.58	98.2
8340	Tents & Tarpaulins	26297	69.18	151.97	589.96	8061.19
8345	Flags & Pennants	25809	1.6	2.92	12.21	236.25
8405	Outerwear Mens	253243	1.58	1.44	37.05	232
8410	Outerwear Womens	105614	1.14	1.16	14.21	103.05
8415	Clothing Special Purpose	412132	1.73	1.57	76.88	1239.3
8420	Underwear & Nightwear Mens	30656	0.3	0.1	89.86	435.65
8430	Footwear Mens	248721	4.52	1.32	104.44	4225.55
8435	Footwear Womens	15656	2.18	0.32	13.38	37.36
8440	Hosiery Handwear & Clothing Access Men	46087	0.23	0.22	44.52	380.5
8445	Hosiery Handwear & Clothing Access Women	5069	0.65	0.84	29.45	226.84
8455	Badges & Insignia	126006	0.09	0.33	10.85	223.2
8460	Luggage	9553	6.24	8.55	176.99	1150.09

Table C1. Continued

FSC	Description	Freq	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
8465	Individual Equip	57290	1.33	2.37	106.67	3012.16
8470	Armor Personal	11459	2.7	3.67	178.78	2652.1
8520	Toilet Soap Shaving Prep - Dentrifices	2	11.79	0	111.98	25
8530	Personal Toiletry Articles	1150	2.42	0.52	32.87	249.48
8540	Toiletry Paper Products	969	23.68	4.82	526.16	1632.83
8940	Special Dietary Foods - Specialty Prep	8	13.07	9.56	1880.67	3545.25
9110	Fuels Solid	508	0.11	0.05	57.9	121.41
9150	Oils Greases Cutting Lubricants & Hyd	108870	60.32	141.44	884.9	11423.01
9160	Misc Waxes Oils & Fats	1884	26.62	86.65	544.11	6677
9310	Paper & Paperboard	51	2026.27	628.12	45126.84	61738.85
9320	Rubber Fabricated Materials	11886	6.45	9.93	77.33	523.33
9330	Plastics Fabricated Materials	22410	17.53	29.35	165.48	605.42
9340	Glass Fabricated Materials	14273	14.16	22.62	85.03	266.75
9350	Refractories & Fire Surfacing Matls	657	35.58	60.86	1462.74	2946.12
9390	Misc Fabricated Nonmetallic Matls	21424	1.87	5.93	21.98	230.42
9505	Wire Nonelectrical Iron & Steel	14605	3.13	10.18	38.93	232.35
9510	Bars & Rods Iron & Steel	28125	7.29	20.42	200.16	943.32
9515	Plate Sheet & Strip Iron & Steel	17640	334.81	931.01	1537.61	15251.34
9520	Structural Shapes Iron & Steel	13217	5.17	7.4	633.43	2774
9525	Wire Nonelectrical Nonferrous Base Metals	5740	2.99	9	28.45	290.45
9530	Bars & Rods Nonferrous Base Metal	15056	9.01	33.16	90.51	342.47
9535	Plate Sheet Strip-Nonferrous Base Metal	30057	70.43	146.87	336.72	1330.56
9540	Structural Shapes Nonferrous Base Metal	10616	1.13	4.28	81.69	492.59
9545	Plate Sheet Strip & Wire Precious Metal	33	0.03	0.03	0.69	1.52
9620	Minerals Natural & Synthetic	105	2.06	3.15	6.71	11.31
9630	Additive Metal Materials & Master Alloys	48	1	0.01	134.81	448.91
9640	Iron & Steel Primary & Semifinished Prod	166	24.11	16.24	446.98	1354.83
9650	Nonferrous Base Metal Refinery	687	3.72	11.96	1421.65	11079.15
9660	Precious Metals Primary Forms	135	6.56	0	83300.11	182838.93
9905	Signs Advertising Displays	102	24.13	40.41	124.38	440.35
9920	Smokers Articles & Matches	59	13.49	0	50.31	103.61
9925	Ecclesiastical Equip Furnishings & Supplie	648	11.83	14.64	47.08	203.21
9930	Memorials Cemetery Mortuary Equip	327	10.37	18.5	282.92	908.11
9999	Misc Items	11	10.03	20.33	348.75	775.24

APPENDIX D

Table D1: 67-Product Aggregation Scheme.

Aggregate Product	Product Groups	Material Description
1	1000	Weapons
2	1200	Fire Control Equipment
3	1400	Guided Missile Components
4	1500/1600	Acft & Airframe Struct Comp; Acft Comps & Accessorie
5	1700	Acft Launch, Ldg & Gnd Handling Equip
6	2000	Ship & Marine Equip
7	2200	Railway Equip
8	2400	Tractors
9	2500	Vehicular Equip Comps
10	2600	Acft Tires
11	2800	Engines, Turbines, & Comps-Acft & Non- Acft
12	2900	Engine Accessories-Acft & Non-Acft
13	3000	Mech Power Transmission Equip
14	3100	Bearings
13	3200	Woodworking Machinery & Equi[p
16	3400	Metalworking Machinery
17	3500	Service & Trade Equip
18	3600	Special Industry Machinery
19	3700	Agricultural Machinery
20	3800	Const, Mining, Excavating & Equip
21	3900	Materials Handing Equip
22	4000	Rope, Cable, Chain, & Fittings
23	4100	Refrigeration & Air Cond Equip
24	4200	Fire Fighting, Rescue & Safety Equip
25	4300	Pumps & Compressors
26	4400	Furnace, Steam Plant, Drying Equip
27	4500	Plumbing, Heating & Sanitation
28	4600	Water Purification & Sewage Treatment Equip
29	4700	Pipe, Tube & Hose
30	4800	Valves
31	4900	Maintenance & Repair Shop Equip
32	5100	Hand Tools
33	5200	Measuring Tools
34	5300	Hardware & Abrasives
35	5400	Prefab Structures & Scaffolding
36	5500	Lumber, Millwork, Plywood & Veneer
37	5600	Construction & Building Material
38	5800	Communication Equip
39	5900	Electrical & Electronic Equip Comps
40	6000	Fiber Optics Mats, Comps, Assys
41	6100	Electric Wire, & Power & Distribution
42	6200	Lighting Fixtures & Lamps
43	6300	Alarm & Signal Systems
44	6500	Medical,Dental & Veterinary Equip
45	6600	Instruments & Laboratory Equip
46	6700	Photographic Equip
47	6800	Chemicals & Chemical Products
48	6900	Training Aids & Devices
49	7000	General Purpose Adpe, Software, Supplies
50	7100	Furniture
51	7200	Household & Coml Furnishings & Appliances
52	7300	Kitchen & Food Prep Equip
53	7400	Office Machines, Visible record Equip
54	7500	Office Supplies & Devices
55	7600	Books, Maps & Other Pubs
56	7900	Cleaning Equip & Supplies
57	8000	Brushes, Paints, Sealers,& Adhesives
58	8100	Containers, Packaging & Packing Suppllies
59	8300	Textiles, Furs,Notions, Tents
60	8400	Clothing
61	8500	Toiletries
62	8900	Specialty Prep
63	9100	Fuels, Lubricants, Oils & Waxes
64	9300	Nonmetallic Fabricated Matls
65	9500	Metal Bars, Sheets and Shapes
66	9600	Ores,Minerals & Their Primary Products
67	9900	Miscellaneous

Table D2. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 67-product aggregation scheme .

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	76864	1.6498	4.568	35.88	437.09
2	8829	1.2201	4.583	6.4	33.39
3	10888	2.3038	4.614	15.16	62.66
4	252986	2.4896	8.606	15.05	162.11
5	24864	12.8468	35.62	66.95	352.67
6	16455	24.5145	71.962	585.21	33568.32
7	164	18.7415	18.667	570.97	1074.23
8	34	52.8491	129.413	97.41	219.8
9	842560	12.0563	34.834	41.63	1657.43
10	1891	14.9542	11.512	50.37	117.03
11	93223	11.4153	43.143	79.25	859.08
12	478240	5.1555	15.557	24.2	1917.98
13	234908	6.2626	25.332	28.17	756.06
14	337067	1.3514	23.511	14.49	636.56
15	2654	20.7057	120.005	32.03	153.44
16	106975	6.0886	49.479	51.34	724.07
17	3571	32.9155	113.265	66.82	247.27
18	5295	20.4824	60.272	109.75	1308.26
19	2189	27.2589	128.675	72.56	349.96
20	13122	56.7634	166.753	260.85	2104.37
21	19128	61.8864	150.282	1055.37	23596.05
22	122656	37.4654	144.134	332.31	34794.65
23	52765	35.8745	131.046	158.26	7441.85
24	87903	9.6327	36.12	154.12	2191.95
25	147569	8.0243	42.851	37.63	2291.25
26	11156	23.4183	86.148	146.38	2295.83
27	49005	13.5113	69.803	91.71	557.22
28	3798	19.1852	55.529	176.35	958.28
29	943225	1.9464	16.069	55.73	7379.39
30	214740	5.3715	28.963	23.82	835.14
31	78993	11.8842	39.623	56.69	844.2
32	1759	0.783	1.025	3.09	8.23
33	1605	2.33	5.133	8.73	53.28
34	4391188	0.6135	8.122	8.07	309.41
35	5993	41.9352	199.939	470.07	3995.39
36	4429	8.158	20.024	11719.99	93763.95
37	1919	54.6003	103.82	4527.65	28018.62
38	61247	2.0532	5.845	28.02	358.85
39	2613533	0.6929	7.082	7.57	342.94
40	386	0.1795	0.452	5.78	29.49
41	306500	7.6605	33.489	214.92	11169.36
42	463588	1.1251	4.265	23.68	686.43
43	16377	2.4206	6.627	13.79	400.53
44	1262831	2.9986	35.295	69.99	1695.08
45	356349	1.9441	10.661	14.91	1267.82
46	32102	9.0303	37.209	122.07	1115.4
47	112441	49.5319	125.205	775.21	18061.48
48	3040	8.0871	45.525	154.44	3476.8
49	25374	1.6873	3.714	36.95	265.43
50	8124	61.8037	92.98	842.13	7841.17
51	22905	6.7524	10.252	590.96	5381.51
52	43773	32.3147	124.335	123.94	1982.69
53	154	40.437	46.854	162.41	384.61
54	3509	45.4172	234.021	401.93	2500.95
55	21953	0.3935	2.377	7.3	273.16
56	712	25.9799	30.179	167.01	948
57	79	2.6921	0.393	15.7	21.66
58	25426	32.5428	50.427	663.34	4925.69
59	101937	18.9205	83.113	924.63	86008.08
60	1321486	1.9611	2.123	64.27	2080.95
61	2121	12.1384	11.084	258.31	1145.2
62	8	13.07	9.557	1880.67	3545.25
63	111262	59.4781	140.487	875.36	11333.11
64	70701	11.8578	60.792	135.42	2109.67
65	135089	62.974	360.568	401.27	5654
66	1141	6.7577	13.342	10783.14	68631.04
67	1147	12.5786	19.484	124.25	540.46

Table D3. 44-Product aggregation scheme.

Aggregate Product	FSC's	Material Description
1	1005 - 1095	Weapons
2	1210 - 1290	Fire Control Equip; Optical Sighting Equip
3	1420 - 1450	Guided Missile Comps
4	1560	Acft & Airframe Struct Comps
	1610 - 1680	Acft Comps & Accessories
	2620	Tires
5	1710 - 1740	Acft Launch, Landing, & Ground Handling Equip
6	2010 - 2090	Ship & Marine Equip
7	2230/2240/2250	Railway Equip
	2410/2420	Tractors
	2510 - 2590	Vehicular Equip
8	2805/2815/2820/2835/2845/2850/2895	Engines, Turbines, & Comps - Non Acft Gas Reciprocating & Diesel Engines; Rocket Engines Steam & Water Turbines; Gas Turbines;
9	2810/2840	Engines, Turbines, & Comps - Acft
10	2910/2920/2930 2940/2950/2990	Engine Accessories - Non Acft; Fuel Systems, Electrical, Cooling Systems, Air & Oil Filters, Turbo
11	2915/2925/2935 2945/2995	Engine Accessories - Acft; Fuel Systems, Electrical Cooling Systems, Air & Oil Filters
12	3010 - 3040	Mech Power Transmission Equip
	3110 - 3130	Bearings
13	3210/3220/3230	Woodworking Machinery & Equip
	3405-3465	Metal Working Machinery & Equip
14	3510-3590	Service & Trade Equip: Laundry & Dry Cleaning, Shoe Repair,Sewing Machines
15	3610-3695	Special Industry Equip
16	3710-3770	Agricultural Machinery & Equip: Soil Prep & Harvesting Equip
	3805-3895	Construction ,Mining, Excavating, & Hwy Equip
17	3910-3990	Materials Handling Equip
18	4010/4020/4030	Rope, Cable, Chain, & Fitting
19	4110-4140	Refrigeration & Air Cond Equip
20	4210-4240	Fire Fighting, Rescue & Safety Equip
21	4310/4320/4330	Pumps & Conpressors
	4410-4460	Furnace, Steam Plant, & Drying Equip
22	4510-4540	Plumbing, Heating & Sanitation Equip
	4610-4630	Water Purification & Sewage Treatment Equip
23	4710-4730	Pipe, Tube & Hose
24	4810/4820	Valves
25	4910-4940	Maintenance & Repair Shop Equip
26	5305-5330 5340-5365	Hardware & Abrasives
27	5335	Metal Screening
	5410-5450	Prefab Structures & Scaffolding
	5510-5530	Lumber,Millwork, Plywood & Veneer
	5620/5660/5680	Building Glass,Tile, Brick & Block,Fencing;Misc Constr Matl
28	5805-5895	Communication Equip
29	5905-5999	Electrical & Electronic Equip Comps
	6010-6080	Fiber Optic Matls, Comps, & Assys
30	6105-6150	Electric Wire, & Power & Distribution
31	6210-6260	Lighting Fixures & Lamps
	6310-6350	Alarm & Signal Systems
32	6505-6550	Medical, Dental, & Veterinary Equip
33	6605-6699	Instruments & Laboratory Equip
34	6710-6780	Photographic Equip
35	6810-6850	Chemicals & Chemical Products
36	6910-6940	Training Aids & Devices
37	7010-7050	Genl Purpose Adpe, Software, Supplies
38	7105-7195	Furniture
	7210/7240/7290	House Furnishings
	7310-7360	Food Prep & Serving Equip
	7430-7490	Office Machines
	7510-7540	Office Supplies & Devices
	7610-7690	Books, Maps & Other Publications
	7710-7730	Musical Instruments, Phonographs, & TV
	8020/8030/8040	Paint Brushes; Preservative Components; Adhesives
39	8105-8145	Containers, Packaging & Packing Supplies
40	8305-8345	Textiles, Furs, Notions, Tents
	8405-8470	Clothing
	8510-8540	Toiletries
41	9110/9150/9160	Fuels, Lubricants, Oils & Waxes
42	9310-9390	Nonmetallic Fabricated Matls
43	9505-9545	Metal Bars, Sheetss and Shapes
	9620-9660	Ores;Minerals
44	9900	Ores, Minerals & Their Primary Products
	8940	Specialty Prep Dietary Foods
	5110/5120/5130	Hand Tools
	5210/5220/5280	Measuring Tools

Table D4. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 44-product aggregation scheme .

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	76864	1.65	4.57	35.88	437.09
2	8829	1.22	4.58	6.40	33.39
3	10888	2.30	4.61	15.16	62.66
4	254877	2.58	8.70	15.31	161.85
5	24864	12.85	35.62	66.95	352.67
6	16455	24.51	71.96	585.21	33568.32
7	842758	12.06	34.84	41.73	1657.32
8	75102	14.00	47.70	83.03	668.31
9	18121	0.70	2.00	63.57	1394.80
10	457152	5.32	15.71	21.10	481.74
11	21088	1.62	11.20	91.44	8853.98
12	571975	3.37	24.40	20.11	688.19
13	109629	6.44	52.37	50.87	715.65
14	3571	32.92	113.27	66.82	247.27
15	5295	20.48	60.27	109.75	1308.26
16	15311	52.55	162.18	233.93	1953.73
17	19128	61.89	150.28	1055.37	23596.05
18	122656	37.47	144.13	332.31	34794.65
19	52765	35.87	131.05	158.26	7441.85
20	87903	9.63	36.12	154.12	2191.95
21	158725	9.11	47.37	45.27	2291.74
22	52803	13.92	68.89	97.80	595.54
23	943225	1.95	16.07	55.73	7379.39
24	214740	5.37	28.96	23.82	835.14
25	78993	11.88	39.62	56.69	844.20
26	4389777	0.60	7.95	7.98	308.58
27	13752	32.04	141.79	4640.62	54528.19
28	61247	2.05	5.85	28.02	358.85
29	2613919	0.69	7.08	7.56	342.92
30	306500	7.66	33.49	214.92	11169.36
31	479965	1.17	4.37	23.34	678.66
32	1262831	3.00	35.30	69.99	1695.08
33	356349	1.94	10.66	14.91	1267.82
34	32102	9.03	37.21	122.07	1115.40
35	112441	49.53	125.21	775.21	18061.48
36	3040	8.09	45.53	154.44	3476.80
37	25374	1.69	3.71	36.95	265.43
38	101209	22.37	98.28	271.90	3674.63
39	25426	32.54	50.43	663.34	4925.69
40	1425544	3.19	22.75	126.08	23087.42
41	111262	59.48	140.49	875.36	11333.11
42	70701	11.86	60.79	135.42	2109.67
43	136230	62.50	359.09	488.23	8485.96
44	4519	4.35	11.40	39.17	321.37

Table D5. 29-Product aggregation scheme.

Aggregate Product	FSC	Material Description
1	1005 - 1095	Weapons
2	1210 - 1290	Fire Control Equip; Optical Sighting Equip
	1420 - 1450	Guided Missile Components
3	1560	Acft & Airframe Structural Components
	1610-1680	Acft Components & Accessories
	1710 - 1740	Acft Launch, Landing, & Ground Handling Equip
	2620	Tires
	2810/2840	Engines, Turbines, & Components - Acft
	2915/2925/2935/2945	Engine, Accessories - Acft; Fuel Systems
	2995	Electrical, Cooling Systems, Air & Oil Filters
4	2010 - 2090	Ship & Marine Equip
5	2230/2240/2250	Railway Equip
	2410/2420	Tractors
	2510-2590	Vehicular Equip
6	2805/2815/2820/2830/ 2835/2845/2850/2895	Engines, Turbines, & Comps - Non Acft Gas Reciprocating &Diesel Engines; Steam & Water Turbines; Gas Turbines, Rocket Engines
	2910/2920/2930/2940/ 2950/2990	Engine Accessories - Non Acft; Fuel Systems, Electrical Cooling Systems, Air & Oli Filters, Turbo Superchargers
7	3010 - 3040	Mech Power Transmission Equip
	3110 - 3130	Bearing
8	3210/3220/3230	Woodworking Machinery & Equip
	3405 -3465	Metal Working Machinery & Equip
	3510 - 3590	Service & Trade Equip; Laundry & Dry Cleaning Equip; Shoe Repair, Sewing Machines
	3610 - 3695	Special Industry Equip
	3910 - 3990	Materials Handling Equip
9	3710 - 3770	Agricultural Mach & Equip; Soil Prep & Harvesting Equip
	3805 - 3895	Construction, Mining, Excavating, & Highway Equip
10	4010 - 4030	Rope, Cable, Chain, & Fittings
11	4110 - 4140	Refrigeration & Air Conditioning Equip
	4510 - 4540	Plumbing, Heating, & Sanitation Equip
	4610 - 4630	Water Purification & Sewage Treatment Equip
	4710 - 4730	Pipe, Tube & Hose
12	4210 - 4240	Fire Fighting, Rescue, & Safety Equip
13	4310 - 4330	Pumps & Compressors
	4410 - 4460	Furnace, Steam Plant, & Drying Equip
14	4810 - 4820	Valves
15	4910 - 4940	Maintenance & Repair Shop Equip
16	5305 - 5365	Hardware & Abrasives
	5410 - 5450	Prefab Structures & Scaffolding
	5510 - 5530	Lumber, Millwork, Plywood & Veneer
	5620\5660\5680	Fencing; Misc Construction Matl
17	5805 - 5895	Communication
18	5905 - 5999	Electrical & Electronic Equip Comps
	6010 - 6080	Fiber Optic Matls, Comps, & Assys
19	6105 - 6150	Electric Wire, & Powe & Distribution
	6210 - 6260	Lighting Fixtures & Lamps
	6310 - 6350	Alarm & Signal Systems
20	6505 - 6550	Medical, Dental, & Veterinary Equip
21	6605 -6699	Instruments & Laboratory Equip
22	6710 - 6780	Photographic Equip
	6910 - 6940	Training Aids & Devices
	7010 - 7050	General Purpose ADPE, Software, Supplies
23	6810 - 6850	Chemicals & Chemical Products
24	7105 - 7540	Furniture
	7210/7240/7290	House Furnishings
	7310 - 7360	Food Prep & Serving Equip
	7430 - 7490	Office Machines
	7510 - 7540	Office Supplies & Devices
	7610 - 7690	Books, Maps, & Other Publications
	7710 - 7730	Musical Instruments, Phonographs, & TV
	8020/8030/8040	Paint Brushes; Preservative Components; Adhesives
	8105 - 8145	Containers, Packaging, & Packing Supplies
25	8305 - 8345	Textiles, Furs, Notions, Tents
	8405 - 8470	Clothing
	8510 - 8540	Toiletries
26	9110/9150/9160	Fuels, Lubricants, Oils, & Waxes
27	9310 - 9390	Nonmetallic Fabricated Matls
28	9505 - 9545	Metal Bars, Shheets, & Shapes
	9620 - 9660	Ores; Minerals
29	9900	Miscellaneous
	8940	Specialty Prep Dietary Foods
	5110/5120/5130	Hand Tools
	5210/5220/5280	Measuring Tools

Table D6. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 29-product aggregation scheme .

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	76864	1.65	4.57	35.88	437.09
2	19717	1.82	4.63	11.23	51.83
3	318950	3.21	13.27	27.12	2307.51
4	16455	24.51	71.96	585.21	33568.32
5	842758	12.06	34.84	41.73	1657.32
6	532254	6.54	23.28	29.84	512.66
7	571975	3.37	24.40	20.11	688.19
8	137623	15.38	78.55	193.16	8830.46
9	15311	52.55	162.18	233.93	1953.73
10	122656	37.47	144.13	332.31	34794.65
11	1048793	4.26	37.35	63.00	7195.74
12	87903	9.63	36.12	154.12	2191.95
13	158725	9.11	47.37	45.27	2291.74
14	214740	5.37	28.96	23.82	835.14
15	78993	11.88	39.62	56.69	844.20
16	4403529	0.70	11.35	22.45	3073.53
17	61247	2.05	5.85	28.02	358.85
18	2613919	0.69	7.08	7.57	342.92
19	786465	3.70	21.42	98.00	6993.49
20	1262831	3.00	35.30	69.99	1695.08
21	356349	1.94	10.66	14.91	1267.82
22	60516	5.90	29.28	88.01	1139.51
23	112441	49.53	125.21	775.21	18061.48
24	126635	24.41	90.82	350.49	3960.76
25	1425544	3.19	22.75	126.08	23087.42
26	111262	59.48	140.49	875.36	11333.11
27	70701	11.86	60.79	135.42	2109.67
28	136230	62.50	359.09	488.23	8485.96
29	4519	4.35	11.40	39.17	321.37

Table D7: 49-Product aggregation scheme.

Aggregate Product	FSC	Material Description
1	1005-1095	Weapons
2	1210-1287	Fire Control Equipment
	1420-1450	Guided Missile Components
3	1560	Airframe Structural Comps
	1610-1680	Aircraft Comps & Accessories
	1710-1740	Aicft Launching,Ldg, & Gnd Handling Equip
	2620	Tires
4	2010-2090	Ship & Marine Equip
5	2230-2250	Railway Equip
	2410/2420	Tractors
	2510	Vehicular Cab Body Frame; Structural Comps
6	2520	Vehicular Power Transmission Comps
7	2530	Vehicular Brake Steering Axle; Wheel Comps
8	2540	Vehicular Furniture & Accessories
9	2590	Misc Vehicular Comps
10	2805-2895	Engines, Turbines, & Comps
	2910-2995	Engine Accessories
11	3010-3040	Mech Power Transmission Equip
12	3110-3130	Bearings
13	3210-3230	Woodworking Machinery & Equip
	3405-3465	Metalworking Equip
	3510-3590	Service & Trade Equip
	3610-3695	Special Industry Equip
14	3710-3770	Agricultural Machinery & Equip
	3805-3895	Const, Mining ,Excavating & Hwy
	3910-3990	Matls Handling Equip
15	4010-4030	Rope, Cable, Chain & Fittings
16	4210-4240	Fire Fighting, Rescue & Safety Equip
17	4110-4140	Refrigeration & Air Cond
	4310-4330	Pumps & Compressors
	4410-4460	Furnace, Steam Plant, Drying Equip
	4510-4540	Plumbing, Heating & Sanitation Equip
	4610-4630	Water Purification & Sewage Treatment Equip
18	4710	Pipe & Tube
19	4720	Hose & Tubing Flexible
20	4730	Fittings, Hose, Pipe, & Tube
21	4810-4820	Valves
22	4910-4940	Maintenance & Repair Shop Equip
	5110-5133	Hand Tools
	5210-5280	Measuring Tools
23	5305	Screws
24	5306	Bolts
	5307	Studs
25	5310	Nuts & Washers
	5340	Misc Hardware
	5355	Knobs & Pointers
	5360	Coil, Flat & Wire Springs
	5365	Rings Shims & Spacers

Table D7. Continued

Aggregate Product	FSC	Material Description
26	5315	Nails Keys & Pins
27	5320	Rivets
	5325	Fastening Devices
28	5330	Packing & Gasket Matls
29	5335	Metal Screening
	5345	Disks & Stones Abrasives
	5350	Abrasive Matls
	5410-5450	Prefabricated Structures; Scaffolding
	5510-5530	Lumber, Millwork, Plywood & Veneer
	5620-5680	Construction &Building Matls
30	5805-5895	Communication Equip
	5905-5970	Electrical Equip: Resistors, Capacitors, Filters, Networks, Circuit Breakers
31	5975-5999	Electrical Hardware
	6010-6099	Fiber Optics
32	6105-6140	Electric Wire & Power & Distribution
	6150/6160	Misc Power & Distribution
33	6145	Electrical Wire & Cable
34	6210-6260	Lighting Fixtures & Lamps
	6310-6350	Alarm & Signal Systems
35	6505	Drums, Biologicals
	6508	Medicated Cosmetics & Tioletries
36	6510	Surgical Dressing Matls
	6532	Hospital & Surgical Clothing
37	6515	Medical Surgical Instruments Equip
	6540	Opticians Instruments Equip
	6545	Medical Sets Kits & Outfits
	6550	In Vitro Diagnostic Substances
38	6520	Dental Instruments Equip
	6525	X-Ray Equip Supplies-Medical/Dental
39	6530	Hospital Furniture Equip
40	6810-6850	Chemical & Chemical Products
41	6910-6940	Training Aids & Devices
	7010-7050	Adpe, Software,Supplies
42	7105-7195	Furniture
	7210-7290	Household & Coml Furniture
	7310-7360	Food Prep & Serving Equip
	7430-7490	Office Machines
43	7510-7540	Office Supplies
	7610-7690	Books, Maps & Other Publications
	7910-7930	Cleaning Equip & Supplies
	8020-8040	Brushes, Paints, Sealers & Adhesives
44	8105-8145	Cotainers, Packaging,& Packing Supplies
	9310-9390	Nonmetallic Fabricated Matls
45	8305-8345	Textiles
	8405/8410	Outerwear
46	8415-8470	Clothing
	8510-8540	Toiletries
47	8940	Special Prep Dietary Foods
	9110-9160	Fuels,Lubricants, Oils & Waxes
48*	9505-9545	Metal Bars & Sheets
	9620-9660	Ores,Minerals
	9905-9999	Misc
49*	6605-6695	Instruments & Laboratory Equip
	6710-6780	Photographic Equip

Table D8. This table provides the summary statistics (total requisitions, average weight per requisition, standard deviation of weight per requisition, average extended weight per requisition, and standard deviation of extended weight per requisition) for the 49-product aggregation scheme .

Aggregate Product	Frequency	Mean Weight	Std Dev Weight	Mean Ext Weight	Std Dev Ext Weight
1	76864	1.65	4.57	35.88	437.09
2	19717	1.82	4.63	11.23	51.83
3	279741	3.49	13.79	19.90	187.45
4	16455	24.51	71.96	585.21	33568.32
5	148096	22.06	38.66	55.79	433.91
6	80748	11.53	36.06	56.02	662.87
7	204992	11.92	47.08	52.42	3277.37
8	311445	8.68	21.89	28.09	350.68
9	97477	8.39	27.43	29.63	338.48
10	571463	6.18	22.62	33.18	1788.67
11	234908	6.26	25.33	28.17	756.06
12	337067	1.35	23.51	14.49	636.56
13	118495	7.87	55.80	53.98	743.17
14	34439	57.73	155.75	690.17	17637.96
15	122656	37.47	144.13	332.31	34794.65
16	87903	9.63	36.12	154.12	2191.95
17	264293	15.41	76.37	78.32	3779.35
18	109665	4.41	30.38	263.81	8003.25
19	237074	3.93	22.65	77.72	13671.49
20	596486	0.70	5.52	8.73	192.25
21	214740	5.37	28.96	23.82	835.14
22	82357	11.46	38.87	54.61	826.87
23	587830	0.50	1.68	10.87	431.50
24	386548	0.48	2.77	8.67	113.39
25	1773715	0.64	6.97	8.74	301.44
26	243988	0.66	7.61	10.77	487.65
27	305445	0.24	2.05	7.79	469.42
28	1092186	0.72	12.53	4.38	125.01
29	13817	31.99	141.47	4618.92	54400.68
30	2222066	0.58	7.04	5.43	360.98
31	453100	1.42	7.10	20.80	237.93
32	190279	10.43	40.44	68.71	3233.20
33	116221	3.13	15.73	454.30	17657.85
34	479965	1.17	4.37	23.34	678.66
35	640987	1.58	5.63	60.05	1963.62
36	91173	3.56	6.33	69.28	513.56
37	351596	3.34	48.83	70.72	924.78
38	119174	3.46	73.10	42.09	2305.57
39	59901	14.35	32.93	228.59	1813.87
40	112441	49.53	125.21	775.21	18061.48
41	28414	2.37	15.42	49.52	1164.97
42	74956	27.72	101.36	344.57	4228.77
43	26253	7.11	87.13	64.40	969.95
44	96127	17.33	58.94	275.06	3121.70
45	460794	5.31	39.78	228.17	40455.04
46	964750	2.17	2.41	77.32	2432.82
47	111270	59.47	140.48	875.43	11332.74
48	137377	62.09	357.63	485.19	8450.67
49	388451	2.53	14.92	23.77	1256.27

APPENDIX E

Table E1: Top 259 U. S cities as identified in SAILS (table continued on the next page)

City	State	3-Digit Zip
Springfield	MA	011
Pittsfield	MA	012
Worcester	MA	016
Boston	MA	021
New Bedford	MA	027
Providence	RI	029
Manchester	NH	031
Portsmouth	NH	038
Portland	ME	041
Lewiston	ME	042
Bangor	ME	044
Burlington	VT	054
Hartford	CN	061
New London	CT	063
Bridgeport	CT	066
Newark	NJ	071
Paterson	NJ	075
Long Branch	NJ	077
Atlantic City	NJ	084
Trenton	NJ	086
New Brunswick	NJ	089
New York	NY	100
Nassau-Suffolk	NY	115
Albany	NY	122
Newburgh	NY	125
Glens Falls	NY	128
Syracuse	NY	132
Utica	NY	135
Binghamton	NY	139
Buffalo	NY	142
Rochester	NY	146
Elmira	NY	149
Pittsburgh	PA	152
Johnstown	PA	159
Sharon	PA	161
Erie	PA	165
Altoona	PA	166
State College	PA	168
Harrisburg	PA	171
York	PA	174
Lancaster	PA	176
Williamsport	PA	177
Allentown	PA	181
Northeast Penna	PA	185
Philadelphia	PA	191
Reading	PA	196
Wilmington	DE	198
Washington	DC	200
Baltimore	MD	212
Cumberland	MD	215
Hagerstown	MD	217
Charlotsville	VA	229
Richmond	VA	232
Norfolk	VA	235
Petersburg	VA	238
Roanoke	VA	240
Lynchburg	VA	245
Charleston	WV	253
Huntington	WV	257
Wheeling	WV	260
Parkersburg	WV	261
Greensboro	NC	274
Raleigh	NC	276
Charlotte	NC	282
Fayetteville	NC	283
Wilmington	NC	284
Jacksonville	NC	285
Hickory	NC	286
Ashville	NC	287
Columbia	SC	292
Charleston	SC	294
Florence	SC	295
Greenville	SC	296
Rock Hill	SC	297
Atlanta	GA	303
Athens	GA	306
Augusta	GA	309
Macon	GA	312
Savannah	GA	314
Albany	GA	317
Columbus	GA	319
Jacksonville	FL	322
Tallahassee	FL	323
Panama City	FL	324
Pensacola	FL	325
Gainesville	FL	326
Orlando	FL	328
Melbourne	FL	329
Miami	FL	331
West Palm Beach	FL	334
Tampa	FL	336
Lakeland	FL	338
Fort Myers	FL	339
Birmingham	AL	352
Tuscaloosa	AL	354
Florence	AL	356
Huntsville	AL	358
Gadsden	AL	359
Montgomery	AL	361
Anniston	AL	362
Mobile	AL	366
Nashville	TN	372
Chatanooga	TN	374
Johnson City	TN	376
Knoxville	TN	379
Memphis	TN	381
Jackson	MS	392
Biloxi	MS	395
Louisville	KY	402
Lexington	KY	405
Owensboro	KY	423
Columbus	OH	432
Toledo	OH	436
Steubenville	OH	439
Cleveland	OH	441
Akron	OH	443
Youngstown	OH	445
Canton	OH	447
Mansfield	OH	449
Cincinnati	OH	452
Dayton	OH	454
Lima	OH	458
Indianapolis	IN	462
Gary	IN	464
South Bend	IN	466
Fort Wayne	IN	468
Kokomo	IN	469
Muncie	IN	473
Bloomington	IN	474
Evansville	IN	477

Table E1: Continued

City	State	3-DIGIT ZIP
Terre Haute	IN	478
Lafayette	IN	479
Detroit	MI	482
Flint	MI	485
Saginaw	MI	486
Lansing	MI	489
Kalamazoo	MI	490
Jackson	MI	492
Grand Rapids	MI	495
Des Moines	IA	503
Waterloo	IA	507
Sioux City	IA	511
Dubuque	IA	520
Cedar Rapids	IA	524
Davenport	IA	528
Milwaukee	WI	532
Madison	WI	537
Green Bay	WI	543
Wausau	WI	544
La Crosse	WI	546
Eau Claire	WI	547
Appleton	WI	549
Minneapolis- St Paul	MN	554
Duluth	MN	558
Rochester	MN	559
St Cloud	MN	563
Sioux Falls	SD	571
Fargo	ND	581
Grand Forks	ND	582
Bismarck	ND	585
Billings	MT	591
Great Falls	MT	594
Chicago	IL	606
Kankakee	IL	609
Rockford	IL	611
Peoria	IL	616
Bloomington	IL	617
Champaign	IL	618
Springfield	IL	627
St Louis	MO	631
Kansas City	MO	641
St Joseph	MO	645
Columbia	MO	652
Springfield	MO	658
Lawrence	KS	660
Topeka	KS	666
Wichita	KS	672
Omaha	NE	681
Lincoln	NE	685
New Orleans	LA	701
Lafayette	LA	705
Lake Charles	LA	706
Baton Rouge	LA	708
Shreveport	LA	711
Monroe	LA	712
Alexandria	LA	713
Pine Bluff	AR	716
Little Rock	AR	722
Fayetteville	AR	727
Fort Smith	AR	729
Oklahoma City	OK	731
Lawton	OK	735
Enid	OK	737
Tulsa	OK	741

City	State	3-Digit Zip
Dallas-Ft Worth	TX	752
Texarkana	TX	755
Long View	TX	756
Tyler	TX	757
Wichita Falls	TX	763
Killeen	TX	765
Waco	TX	767
San Angelo	TX	769
Houston	TX	770
Galveston	TX	775
Beaumont	TX	777
Bryan	TX	778
Victoria	TX	779
San Antonio	TX	782
Corpus Christi	TX	784
Mcallen	TX	785
Austin	TX	787
Amarillo	TX	791
Lubbock	TX	794
Abilene	TX	796
Odessa	TX	797
El Paso	TX	799
Denver	CO	802
Fort Collins	CO	805
Greeley	CO	806
Colorado Springs	CO	809
Pueblo	CO	810
Casper	WY	826
Boise	ID	837
Salt Lake City	UT	841
Provo	UT	846
Phoenix	AZ	850
Tucson	AZ	857
Albuquerque	NM	871
Las Cruces	NM	880
Las Vegas	NV	891
Reno	NV	895
Los Angeles	CA	900
San Diego	CA	921
Riverside	CA	925
Anaheim	CA	928
Oxnard	CA	930
Bakersfield	CA	933
Fresno	CA	937
Salinas	CA	939
San Franciscon	CA	941
Vallejo	CA	945
San Jose	CA	951
Stockton	CA	952
Santa Rosa	CA	954
Sacramento	CA	958
Chicago	CA	959
Redding	CA	960
Portland	OR	972
Salem	OR	973
Eugene	OR	974
Medford	OR	975
Seattle	WA	981
Bellingham	WA	982
Tacoma	WA	984
Olympia	WA	985
Yakima	WA	989
Spokane	WA	992
Richland	WA	993

Table E2. This table provides the 113-customer aggregations by city and three-digit zip code.

CITY	STATE	3-DIGIT ZIP CODE
LOS ANGELES	CA	900
CHICAGO	IL	606
PHILADELPHIA	PA	191
BOSTON	MA	021
SAN FRANCISCO	CA	941
WASHINGTON	DC	200
DALLAS-FT WORTH	TX	752
NASSAU-SUFFOLK	NY	115
ST LOUIS	MO	631
BALTIMORE	MD	212
ATLANTA	GA	303
ANAHEIM	CA	928
NEWARK	NJ	071
SAN DIEGO	CA	921
MIAMI	FL	331
DENVER	CO	802
SEATTLE	WA	981
TAMPA	FL	336
RIVERSIDE	CA	925
PHOENIX	AZ	850
PORTLAND	OR	972
NEW ORLEANS	LA	701
INDIANAPOLIS	IN	462
COLUMBUS	OH	432
SAN ANTONIO	TX	782
SACRAMENTO	CA	958
ROCHESTER	NY	146
SALT LAKE CITY	UT	841
MEMPHIS	TN	381
LOUISVILLE	KY	402
PROVIDENCE	RI	029
NASHVILLE	TN	372
OKLAHOMA CITY	OK	731
DAYTON	OH	454
NORFOLK	VA	235
JACKSONVILLE	FL	322
ORLANDO	FL	328
WORCESTER	MA	016
NE PENNA	PA	185
RICHMOND	VA	232
OMAHA	NE	681
AUSTIN	TX	787
TUCSON	AZ	857
OXNARD	CA	930
RALEIGH	NC	276
WILMINGTON	DE	198
LONGBRANCH	NJ	077
TACOMA	WA	984
EL PASO	TX	799
LAS VEGAS	NV	891
ALBUQUERQUE	NM	871
HARRISBURG	PA	171
CHARLESTON	SC	294
CHATTANOOGA	TN	374
PORTSMOUTH	NH	038
COLUMBIA	SC	292
BAKERSFIELD	CA	933

CITY	STATE	3-DIGIT ZIP CODE
LITTLE ROCK	AR	722
DAVENPORT	IA	528
SHREVEPORT	LA	711
STOCKTON	CA	952
SPOKANE	WA	992
VALLEJO	CA	945
AUGUSTA	GA	309
CORPUS CHRISTI	TX	784
JACKSON	MS	392
COLORADO SPRINGS	CO	809
UTICA	NY	135
EVANSVILLE	IN	477
HUNTSVILLE	AL	358
TRENTON	NJ	086
SALINAS	CA	939
PENSACOLA	FL	325
MELBOURNE	FL	329
MONTGOMERY	AL	361
NEWBURGH	NY	125
MACON	GA	312
FAYETTEVILLE	NC	283
COLUMBUS	GA	319
NEW LONDON	CT	063
SAVANNAH	GA	314
KILLEEN	TX	765
LUBBOCK	TX	794
SPRINGFIELD	MO	658
RENO	NV	895
ATLANTIC CITY	NJ	084
BILOXI	MS	395
TOPEKA	KS	666
BOISE	ID	837
GREEN BAY	WI	543
ALEXANDRIA	LA	713
WILMINGTON	NC	284
BANGOR	ME	044
PETERSBURG	VA	238
TEXARKANA	TX	755
PUEBLO	CO	810
ANNISTON	AL	362
ALBANY	GA	317
HAGERSTOWN	MD	217
JACKSONVILLE	NC	285
LAWTON	OK	735
BELLINGHAM	WA	982
GADSDEN	AL	359
COLUMBIA	MO	652
GRAND FORKS	ND	582
LEWISTON	ME	042
PANAMA CITY	FL	324
LA CROSSE	WI	546
SHERMAN	TX	750
BISMARCK	ND	585
GREAT FALLS	MT	594
CASPER	WY	826
LAWRENCE	KS	660

Table E3 This table provides the 199-customer aggregations by city and three-digit zip code (table continued on the next page)

CITY	STATE	3-DIGIT ZIP CODE
LOS ANGELES	CA	900
CHICAGO	IL	606
PHILADELPHIA	PA	191
BOSTON	MA	021
SAN FRANCISCO	CA	941
WASHINGTON	DC	200
DALLAS-FT WORTH	TX	752
NASSAU-SUFFOLK	NY	115
ST LOUIS	MO	631
BALTIMORE	MD	212
ATLANTA	GA	303
ANAHEIM	CA	928
NEWARK	NJ	071
SAN DIEGO	CA	921
MIAMI	FL	331
DENVER	CO	802
SEATTLE	WA	981
TAMPA	FL	336
RIVERSIDE	CA	925
PHOENIX	AZ	850
PORTLAND	OR	972
NEW ORLEANS	LA	701
INDIANAPOLIS	IN	462
COLUMBUS	OH	432
SAN ANTONIO	TX	782
SACRAMENTO	CA	958
ROCHESTER	NY	146
SALT LAKE CITY	UT	841
MEMPHIS	TN	381
LOUISVILLE	KY	402
PROVIDENCE	RI	029
NASHVILLE	TN	372
OKLAHOMA CITY	OK	731
DAYTON	OH	454
NORFOLK	VA	235
JACKSONVILLE	FL	322
ORLANDO	FL	328
WORCESTER	MA	016
NE PENNA	PA	185
RICHMOND	VA	232
OMAHA	NE	681
AUSTIN	TX	787
TUCSON	AZ	857
OXNARD	CA	930
RALEIGH	NC	276
WILMINGTON	DE	198
LONGBRANCH	NJ	077
TACOMA	WA	984
EL PASO	TX	799
LAS VEGAS	NV	891

CITY	STATE	3-DIGIT ZIP CODE
ALBUQUERQUE	NM	871
HARRISBURG	PA	171
CHARLESTON	SC	294
CHATTANOOGA	TN	374
PORTSMOUTH	NH	038
COLUMBIA	SC	292
BAKERSFIELD	CA	933
LITTLE ROCK	AR	722
DAVENPORT	IA	528
SHREVEPORT	LA	711
STOCKTON	CA	952
SPOKANE	WA	992
VALLEJO	CA	945
AUGUSTA	GA	309
CORPUS CHRISTI	TX	784
JACKSON	MS	392
COLORADO SPRINGS	CO	809
UTICA	NY	135
EVANSVILLE	IN	477
HUNTSVILLE	AL	358
TRENTON	NJ	086
SALINAS	CA	939
PENSACOLA	FL	325
MELBOURNE	FL	329
MONTGOMERY	AL	361
NEWBURGH	NY	125
MACON	GA	312
FAYETTEVILLE	NC	283
COLUMBUS	GA	319
NEW LONDON	CT	063
SAVANNAH	GA	314
KILLEEN	TX	765
LUBBOCK	TX	794
SPRINGFIELD	MO	658
RENO	NV	895
ATLANTIC CITY	NJ	084
BILOXI	MS	395
TOPEKA	KS	666
BOISE	ID	837
GREEN BAY	WI	543
ALEXANDRIA	LA	713
WILMINGTON	NC	284
BANGOR	ME	044
PETERSBURG	VA	238
TEXARKANA	TX	755
PUEBLO	CO	810
ANNISTON	AL	362
ALBANY	GA	317
HAGERSTOWN	MD	217
JACKSONVILLE	NC	285

Table E3. Continued

CITY	STATE	3-DIGIT ZIP CODE
LAWTON	OK	735
BELLINGHAM	WA	982
GADSDEN	AL	359
COLUMBIA	MO	652
GRAND FORKS	ND	582
LEWISTON	ME	042
PANAMA CITY	FL	324
LA CROSSE	WI	546
SHERMAN	TX	750
BISMARCK	ND	585
GREAT FALLS	MT	594
CASPER	WY	826
LAWRENCE	KS	660
CLEVELAND	OH	441
CINCINNATI	OH	452
MILWAUKEE	WI	532
KANSAS CITY	MO	641
BUFFALO	NY	142
GREENSBORO	NC	274
BRIDGEPORT	CT	066
ALBANY	NY	122
TOLEDO	OH	436
TULSA	OK	741
AKRON	OH	443
SYRACUSE	NY	132
GREENVILLE	SC	296
YOUNGSTOWN	OH	445
FRESNO	CA	937
BATON ROUGE	LA	708
PATERSON	NJ	075
JOHNSON CITY	TN	376
FORT WAYNE	IN	468
MADISON	WI	537
HUNTINGTON	WV	257
MCALLEN	TX	785
KALAMAZOO	MI	490
MANCHESTER	NH	031
CHARLESTON	WV	253
DULUTH	MN	558
JOHNSTOWN	PA	159
ROANOKE	VA	240
GALVESTON	TX	775
LINCOLN	NE	685
WHEELING	WV	260
FAYETTEVILLE	AR	727
TERRE HAUTE	IN	478
CHAMPAIGNE	IL	618
PARKERSBURG	WV	261
MONROE	LA	712
FARGO	ND	581

CITY	STATE	3-DIGIT ZIP CODE
FLORENCE	AL	356
ATHENS	GA	306
MANSFIELD	OH	449
SIOUX CITY	IA	511
ODESSA	TX	797
CHARLOTSVILLE	VA	229
FLORENCE	SC	295
SIOUX FALLS	SD	571
BILLINGS	MT	591
GLENS FALLS	NY	128
KOKOMO	IN	469
KANKAKEE	IL	609
BLOOMINGTON	IN	474
PINE BLUFF	AR	716
SAN ANGELO	TX	769
ENID	OK	737
NEW YORK	NY	100
DETROIT	MI	482
HOUSTON	TX	770
PITTSBURGH	PA	152
MINNEAPOLIS - ST PA	MN	554
HARTFORD	CN	061
BIRMINGHAM	AL	352
CHARLOTTE	NC	282
SPRINGFIELD	MA	011
KNOXVILLE	TN	379
NEW BEDFORD	MA	027
LANSING	MI	489
MOBILE	AL	366
WICHITA	KS	672
PEORIA	IL	616
DES MOINES	IA	503
LEXINGTON	KY	405
ROCKFORD	IL	611
PORTLAND	ME	041
SAGINAW	MI	486
FORT SMITH	AR	729
SPRINGFIELD	IL	627
YAKIMA	WA	989
ST CLOUD	MN	563
FORT COLLINS	CO	805
CHICAGO	CA	959
ABILENE	TX	796
TUSCALOOSA	AL	354
MEDFORD	OR	975
WICHITA	TX	763
BURLINGTON	VT	054
CUMBERLAND	MD	215
LAS CRUCES	NM	880

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